Gift of Mrs. H. H. Graham.

THE STUDY OF ANIMAL LIFE

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PREFACE

For about a quarter of a century this book—now revised—has had an apparently useful life as an introduction to zoological science. Its plan is simple:

(*a*) It begins with the everyday life of animals, their haunts, their inter-relations, their struggles, their industries, their family life, their behaviour, and their internal activities.

(*b*) The second aspect considered is that of structure—the multitudinous forms of animal life and their architecture.

(*c*) The third part has to do with the continuance of the race and with life-histories.

(*d*) Finally, the facts and problems of evolution are illustrated.

The four parts of the book correspond broadly to Physiology, Morphology, Embryology, and Ætiology, but there has been no punctilious observation of boundary-lines.

The four parts of the book will appeal to students of different tastes. For some are most interested in habits and functions, others in form and structure, others in development and life-history, and others in the general problems of evolution. Each of these aspects has its own interest, and the student should begin with the one which most attracts him. But all must be taken into account if we are to get an all-round view of animal life.

J. A. T.

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THE STUDY OF ANIMAL LIFE

PART I

THE ACTIVITIES OF ANIMALS

CHAPTER I

THE WEALTH OF LIFE

1. Variety of life—2. Haunts of life—3. Wealth of form—4. Wealth of numbers—5. Wealth of beauty.

THERE can be no real appreciation of animal life without watching and searching, touching and testing. No book-lore can take the place of personal observation, and though opportunities vary greatly, some are within the reach of all. Within a few hours' walk of even the largest of our towns the country is open and the animals are at home. Though we may not be able to see "the buzzard homing herself in the sky, the snake sliding through creepers and logs, the elk taking to the inner passes of the woods, or the razor-billed auk sailing far north to Labrador," we can watch some of the birds building their "homes without hands," we can study the frogs from the time that they trumpet in the early spring till they or their offspring seek winter quarters in the mud, we can follow the bees and detect their adroit burglary of the flowers. And if we are discontented with our opportunities, let us read Gilbert White's *History of Selborne*, or how Darwin watched earthworms for half a lifetime, or how Richard Jefferies saw in the fields and

hedgerows of Wiltshire a vision of nature, which seemed every year to grow richer in beauty and marvel. It is thus that the study of Natural History should begin, as it does naturally begin in childhood, and as it began long before there was any exact Zoology,—with the observation of animal life in its familiar forms. The country schoolboy, who watches the squirrels hide the beech nuts and pokes the hedgehog into a living ball, who finds the nest of the lapwings, though they decoy him away with prayerful cries, who catches the speckled trout in spite of all their caution, and puzzles over the ants as they find their way home heavily laden with booty, is laying the foundation of a naturalist's education, which, though he may never build upon it, is certainly the surest. For it is in such studies that we get close to life.

The same truth has been vividly expressed by one whose own life-work shows that thoroughness as a zoologist is consistent with enthusiasm for open-air natural history. Of the country lad Dr. C. T. Hudson says, in a Presidential Address to the Royal Microscopical Society, that he "wanders among fields and hedges, by moor and river, sea-washed cliff and shore, learning zoology as he learnt his native tongue, not in paradigms and rules, but from Mother Nature's own lips. He knows the birds by their flight and (still rarer accomplishment) by their cries. He has never heard of *Œdicnemus crepitans*, the *Charadrius pluvialis*, or the *Squatarola cinerea*, but he can find a plover's nest, and has seen the young brown peewits peering at him from behind their protecting clods. He has watched the cunning flycatcher leaving her obvious and yet invisible young in a hole in an old wall, while she carries off the pellets that might betray their presence; and has stood so still to see the male redstart that a field-mouse has curled itself on his warm foot and gone to sleep."

But the student must also attempt more careful studies of living animals, for it is easy to remain satisfied with vague "general impressions." He should make for himself —to be corrected afterwards by the labours of others—a "Fauna" and "Flora" of the district, or a "Naturalist's

Year Book" of the flow and ebb of the living tide. He should select some nook or pool for special study, seeking a more and more intimate acquaintance with its tenants, watching them first and using the eyes of other students afterwards. Nor is there any difficulty in keeping at least freshwater aquaria—simply glass globes with pond water and weeds—in which, within small compass, much wealth of life may be observed. Those students are specially fortunate who have within reach such collections as the Zoological Gardens and the British Museum in London; but this is no reason for failing to appreciate the life of the sea-shore, the moor-pond, and the woods, or for neglecting to gain the confidence of fishermen and gamekeepers, or of any whose knowledge of natural history has been gathered from the experience of their daily life.

1. **Variety of Life.**—Between one form of life and another there often seems nothing in common save that both are alive. Thus life is characteristically asleep in plants, it is generally more or less awake in animals. Yet among the latter, does it not doze in the tortoise, does it not fever in the hot-blooded bird? Or contrast the phlegmatic amphibian and the lithe fish, the limpet on the rock and the energetic squid, the barnacle passively pendent on the floating log and the frolicsome shrimp, the cochineal insect like a gall upon the leaf and the busy bee, the sedentary corals and the free-swimming jellyfish, the sponge on the rock and the minute Night-Light Infusorians which make the waves sparkle in the summer darkness. No genie of Oriental fancy was more protean than the reality behind the myth—the activity of life.

2. **Haunts of Life.**—The variety of haunt and home is not less striking. There is the great and wide sea with swimming things innumerable, our modern giants the whales, the seals and walruses and the sluggish sea-cows, the flippered penguins and Mother Carey's chickens, the marine turtles and swift poisonous sea-serpents, the true fishes in prolific shoals, the cuttles and other pelagic molluscs; besides hosts of armoured crustaceans, swiftly

gliding worms, fleets of Portuguese Men-of-War and throbbing jelly-fish, and minute forms of life as numerous in the waves as motes in the sunlit air of a dusty town.

> "But what an endless worke have I in hand,
> To count the seas abundant progeny,
> Whose fruitful seede farre passeth those on land,
> And also those which wonne in th' azure sky;
> For much more eath to tell the starres on hy,
> Albe they endlesse seem in estimation,
> Than to recount the seas posterity;
> So fertile be the floods in generation,
> So huge their numbers, and so numberlesse their nation."

Realise Walt Whitman's vivid picture :—

> "The World below the brine.
> Forests at the bottom of the sea—the branches and leaves,
> Sea-lettuce, vast lichens, strange flowers and seeds—the thick tangle, the openings, and the pink turf,
> Different colours, pale grey and green, purple, white, and gold—the play of light through the water,
> Dumb swimmers there among the rocks—coral, gluten, grass, rushes—and the aliment of the swimmers,
> Sluggish existences grazing there, suspended, or slowly crawling close to the bottom:
> The sperm-whale at the surface, blowing air and spray, or disporting with his flukes,
> The leaden-eyed shark, the walrus, the turtle, the hairy sea-leopard, and the sting ray.
> Passions there, wars, pursuits, tribes—sight in those ocean depths—breathing that thick breathing air, as so many do."

The sea appears to have been the cradle, if not the birthplace, of the earliest forms of animal life, and some have never wandered out of hearing of its lullaby. From the sea, animals seem to have migrated to the shore and thence to the land, but also to the great depths. Of the abundant life of the great abysses there has been rapidly increasing knowledge since the memorable time when the *Challenger* expedition (1872-76), under Sir Wyville Thomson's leadership, following the suggestions gained during the laying of the Atlantic cables and the tentative voyages of the *Lightning* (1868) and the *Porcupine* (1870), revealed what was virtually a new world. During 3½

Fig. 1.—Suggestion of Deep-sea Life.
(In part from a figure by W. Marshall.)

years the *Challenger* explorers cruised over 68,900 nautical miles, reached with the long arm of the dredge to depths equal to reversed Himalayas, raised sunken treasures of life from over 300 stations, and brought home spoils which for about twenty years kept the savants of Europe busily at work, the results, under Sir John Murray's editorship, forming a library of about forty huge volumes. The discovery of this new and strange world not only yielded rich treasures of knowledge, but raised a widespread enthusiasm for ocean-exploring which has not since died away.

We are at present mainly interested in the general picture which the results of these deep-sea explorations present,—of a thickly-peopled region far removed from direct observation, sometimes three to six miles beneath the surface—a world of darkness relieved only by the living lamps of phosphorescence, of silent calm in which animals grow into quaint forms, of great uniformity throughout wide areas, and moreover a cold and plantless world in which the animals have it all their own way, feeding on their neighbours, and ultimately upon the small organisms which in dying sink gently from the surface like snowflakes through the air.

Far otherwise is it on the shore—sunlight and freshening waves, continual changes of time and tide, abundant plants, crowds of animals, and a scrimmage for food. The shore is one of the great battlefields of life on which, through campaign after campaign, animals have sharpened one another's wits. It has been for untold ages a great school.

Leaving the sea-shore, the student might naturally seek to trace a migration of animals from sea to estuary, and from the brackish water to river and lake; and this path has been followed by some animals. In other cases, however, shallow continental seas have been converted into freshwater lakes, and some of the originally marine inhabitants have been transformed into freshwater species. In other cases accumulations of fresh water have been formed apart from any seas, and these have been in great part stocked by aquatic birds which

carry small animals and the larvæ of larger animals on their muddy feet from one basin to another. Others are borne by the wind, and changes of land-level may bring different river-beds into communication. In a true lake, as in the sea, it is necessary to distinguish three faunas —of the shore, of the surface, and of the deep water.

As we review the series of animals from the simplest upwards, we find a gradual increase in the number of those which live on land. The lowest animals are mostly aquatic—the sponges and stinging-animals wholly so; worm-like forms which are truly terrestrial are few compared with those in water; the members of the starfish group are wholly marine; among crustaceans, the wood-lice, the land-crabs, and a few other dwellers on the land, are in a small minority; there are many insects which spend their larval life or even their whole life in the water, but their numbers are small compared with the terrestrial and aerial hosts; among spiders aquatic forms are quite exceptional; and while the great majority of molluscs live in water, the terrestrial snails and slugs are legion. In the series of backboned animals, again, the lowest forms are wholly aquatic; an occasional fish like the climbing-perch is able to live for a time ashore; the mud-fish, which can survive being brought from Africa to Europe within its dry "nest" of mud, has learned to breathe in air as well as in water; the amphibians really mark the transition from water to dry land, and usually rehearse the story in each individual life as they grow from fish-like tadpoles into frog- or newt-like adults. Among reptiles, however, begins that possession of the earth, which in mammals is established and secure. As insects among the backboneless, so birds among the backboned possess the air, achieving in perfection what flying fish, swooping tree-frogs and lizards, and above all the ancient and extinct Pterodactyls, have reached towards. Interesting, too, are the exceptions—non-flying terrestrial birds like ostriches, non-flying aquatic penguins, aquatic mammals like the whales, aerial mammals like the bats, and so on.

But it is enough to emphasise the fact of a general

ascent from sea to shore, from shore to dry land, and eventually into the air, and the fact that the haunts and homes of animals are not less varied than the pitch of their life. In addition to minor haunts such as brackish water, burrows, caves, and the interior of other animals, six main haunts of life may be distinguished—the surface of the sea (pelagic), the depths of the sea (abyssal), the shore (littoral), the fresh waters, the dry land, and the air.

3. **Wealth of Form.**—As our observations accumulate, the desire for order asserts itself, and, like our forefathers, we cannot help classifying, allowing similar impressions to draw together into groups, such as birds and beasts, fishes and worms. At first sight the types of architecture seem confusingly numerous, but gradually certain great samenesses are discerned. Thus we distinguish as *higher* animals those which have a supporting rod along the back, and a nerve cord lying above this; while the *lower* animals have no such supporting rod, and have their nerve-cord (when present) on the under, not on the upper side of the body. The higher or backboned series has its double climax in the Birds and the furred Mammals. Indissolubly linked to the Birds are the Reptiles,—lizards and snakes, tortoises and crocodiles—the survivors of a great series of ancient forms, from among which Birds, and perhaps Mammals also, long ago arose. Simpler in many ways, as in bones and brains, are Amphibians and Fishes in close structural alliance, with the strange double-breathing, gill- and lung-possessing mud-fishes as links between them. Far more old-fashioned than Fishes, though popularly included along with them, are the Round-mouths—the half-parasitic hag-fish, and the palatable lampreys, with quaint young sometimes called "nine-eyes." Near the base of this series are the lancelets, small, almost translucent animals living in the sea-sand. Just at the threshold of the higher school of life, the sea-squirts or Tunicates have for the most part stumbled; for though the active young forms—like minute tadpoles—are indisputable Vertebrates, almost all the adults fall from this estate, and

become so degenerate that no zoologist ignorant of their life-history could recognise their true position. Below this come certain claimants for Vertebrate distinction, notably the Enteropneusts, such as *Balanoglossus*, which serve to link the backboneless and the backboned together. They are either worm-like vertebrates or vertebrate-like worms.

Across the line, among the backboneless animals, it is more difficult to distinguish successive grades of higher and lower, for the various classes have progressed in very different directions. We may liken the series to a school in which graded standards have given place to classes which have "specialised" in diverse studies; or to a tree whose branches, though originating at different levels, are all strong and perfect. Of the shelled animals or Molluscs there are three great sub-classes, (*a*) the cuttlefishes and the pearly nautilus, (*b*) the snails and slugs, both terrestrial and aquatic, and (*c*) the bivalves, such as cockle and mussel, oyster and clam. Simpler than all these are a few forms which link molluscs to worms.

Clad in armour of a very different type from the shells of most Molluscs are the jointed-footed animals or Arthropods, including on the one hand the almost exclusively aquatic crustaceans, crabs and lobsters, barnacles and "water-fleas," and on the other hand the almost exclusively aerial or terrestrial spiders and scorpions, insects and centipedes, besides quaint allies like the "king-crab," the last of a strong race. Again a connecting class demands special notice,—the Onychophora, such as *Peripatus*, old-fashioned, widely represented terrestrial animals of caterpillar-like or worm-like appearance. They breathe by air-tubes, somewhat like those of insects; they get rid of their nitrogenous waste-products by means of kidney-tubes somewhat like those of certain worms.

Very different from all these are the starfishes, brittle-stars, feather-stars, sea-urchins, and sea-cucumbers, animals mostly sluggish and calcareous, deserving their title of thorny-skinned or Echinoderma.

"Worms" form a vast, heterogeneous "mob," heart-breaking to those who love order. No zoologist ever speaks of them now as a "class"; the title includes many classes, bristly sea-worms and the familiar earthworms, smooth suctorial leeches, ribbon-worms or Nemerteans, cylindrical thread-worms or Nematodes, flat tapeworms and flukes, and many others with hardly any characters in common. These many kinds of "worms" are full of interest, for in the past they must have been rich in progress, and zoologists find among them the bases of the other great branches—Vertebrates, Molluscs, Arthropods, and Echinoderms. "Worms" lie (as it were) in a central pool, from which flow many streams.

Lower still, and in marked contrast to the rest, are the Stinging-animals, such as jellyfish throbbing in the tide, zoophytes clustering like plants on the rocks, sea-anemones like bright flowers, corals half-smothered with lime. The Sponges are the lowest animals with "bodies." They form a branch of the tree of life which has many beautiful leaves, but has never risen far.

Beyond this our unaided eyes will hardly lead us, yet the pond-water held between us and the light shows vague specks like living motes, the firstlings of life, the simplest animals or Protozoa, almost all of which have remained mere unit specks of living matter, with complexities indeed, but at a microscopically minute level.

It is easy to write this catalogue of the chief forms of life, and yet easier to read it: to have the tree of life as a living picture is an achievement. It is worth while to think and dream over a bird's-eye view of the animal kingdom—to secure representative specimens, to arrange them in a suitably shelved cupboard, so that the outlines of the picture may become clear in the mind. The arrangement of animals on a genealogical or pedigree tree may be readily abused, but it has its value in presenting a vivid image of the organic unity of the animal kingdom.

If the catalogue be thus realised, if the foliage come to represent animals actually known, and if an attempt be made to learn the exact nature, limits, and meaning of

the several branches, the student has made one of the most important steps in the study of animal life. Much

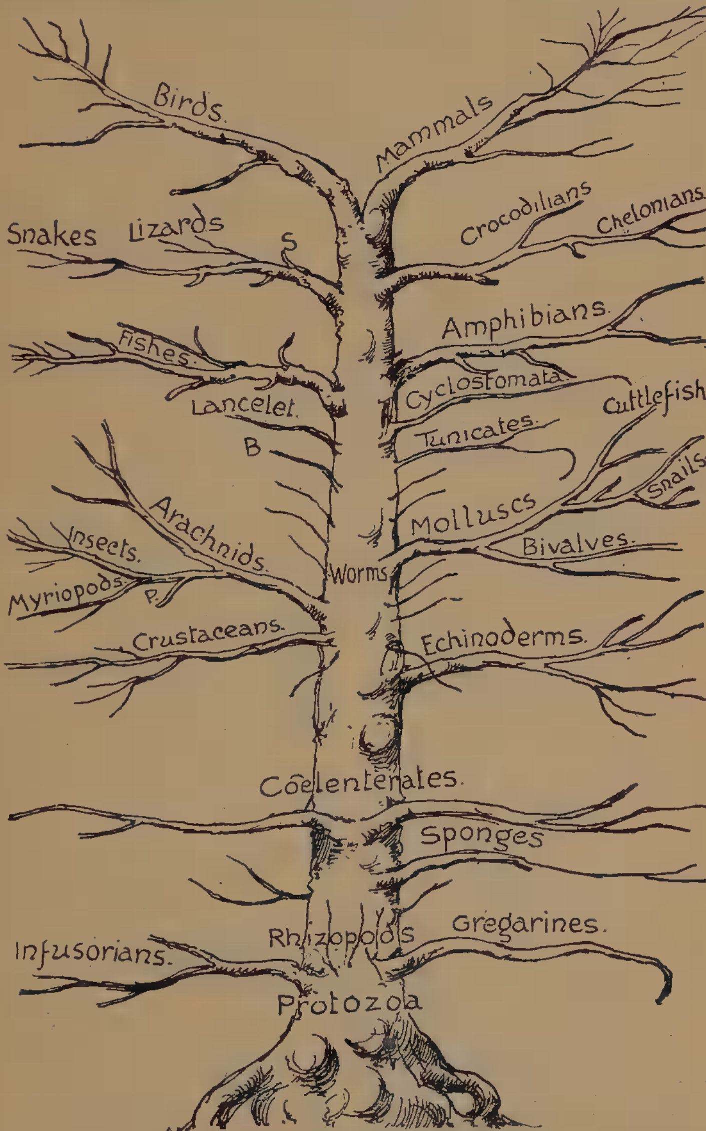


FIG. 2.—GENEALOGICAL TREE.

The small branches in the centre indicate the classes of "worms"; the letters *P*, *B*, and *S* indicate the positions of Peripatus, Balanoglossus, and Sphenodon or Hatteria respectively.

will remain indeed—to connect the living twigs with those whose leaves fell off ages ago, to understand the continual renewal of the foliage by the emergence of new leaves, and finally to understand how the entire tree of life has grown to be what it is.

There is of course no doubt as to the fact that some forms of life are more complex than others. It requires no faith to allow that the firstlings or Protozoa are simpler than all the rest; that sponges, which are more or less loose colonies of unit masses imperfectly compacted together, are in that sense simpler than jellyfish, and so on. The animals most like ourselves are more intricate and more perfectly controlled organisms than those which are obviously more remote, and associated with this perfecting of structure there is an increasing fulness and freedom of life. The standards which we use in calling animals "high" or "low" are two: the first is differentiation, which means complexity of structure, the second is integration, which means unification of structure.

We may arrange all the classes in series from low to high, from simple to complex, but this will express only our most generalised conceptions. For within each class there is great variety, each has its own masterpieces. Thus the simplest animals are often cased in shells of flint or lime whose crystalline architecture has great complexity. The simplest sponge is little more than a double-walled sack riddled by pores through which the water is lashed, but the Venus' Flower-Basket (*Euplectella*), one of the flinty sponges, has a complex system of water canals and a skeleton of flinty threads built up into a framework of marvellous intricacy and grace. The lowest insect is not much more intricate, centralised, or controlled than many a worm of the sea-shore, but the ant or the bee is a very complex self-controlled organism. More exact, therefore, than any linear series, is the image of a tree with branches springing from different levels, each branch again bearing twigs some of which rise higher than the base of the branch above. A perfect scheme of this sort might not only express the facts of

structure, it might also express our notions of the blood-relationships of animals and of the way in which the different forms have arisen.

But the wealth of form is less varied than at first sight appears. There is great wealth, but the coinage is very uniform. Our first impression is one of manifold variety; but that gives place to one of marvellous plasticity when we see how structures apparently quite different are reducible to the same general plan. Thus, as the poet Goethe first clearly showed, the seed-leaves, root-leaves, stem-leaves, and even the parts of the flower—sepals, petals, stamens, and carpels, are in reality all leaves or appendages more or less modified for diverse work. The mouth-parts of a lobster are masticating legs, and a bird's wing is a modified arm. The old naturalists were so far right in insisting on the fact of a few great types.

4. **Wealth of Numbers.**—Large numbers are so unthinkable, and accuracy in census-taking is so difficult, that we need say little as to the number of different animals. The census includes far over a million living species—a total so vast that, so far as our power of realising it is concerned, it is hardly affected when we admit that more than half are insects. To these recorded myriads, moreover, many newly-discovered forms are added every year—now by the individual workers who with fresh eye or improved microscope find in wayside pond or shore pool some new thing, or again by great enterprises like the *Challenger* expedition. Exploring naturalists return from tropical countries enriched with new animals from the dense forests or warm seas. Zoological Stations, notably that of Naples, are "register-houses" for the fauna of the neighbouring sea, not merely as to number and form, but in many cases taking account of life and history as well. Nor can we forget the stupendous roll of the extinct, to which the zoological historians continue to add as they disentomb primitive mammals, toothed birds, giant reptiles, huge amphibians, armoured fishes, gigantic cuttles, and a vast multitude of strange forms, the like of which no longer live. The length of the *Zoological Record*, in which the literature

and discoveries of each year are chronicled, the portentous size of a volume which professes to discuss with some completeness even a single sub-class, the number of special departments into which the science of zoology is divided, suggest the vast wealth of numbers at first sight so bewildering. More than two thousand years ago Aristotle recorded a total of about 500 forms, but more new species may be described in a single volume of the *Challenger* Reports. We speak about the number of the stars, yet more than one family of insects is credited with including as many different species as there are stars to count on a clear night. But far better than any literary attempt to estimate the numerical wealth of life is some practical observation, some attempted enumeration of the inmates of your aquarium, of the tenants of some pool, or of the visitors to some meadow. The naturalist as well as the poet spoke when Goethe celebrated Nature's wealth: "In floods of life, in a storm of activity, she moves and works above and beneath, working and weaving, an endless motion, birth and death, an infinite ocean, a changeful web, a glowing life; she plies at the roaring loom of time and weaves a living garment for God."

5. **Wealth of Beauty.**—To many, however, animal life is impressive not so much because of its amazing variety and numerical greatness, nor because of its intellectual suggestiveness and practical utility, but chiefly on account of its beauty. This is to be seen and felt rather than described or talked about.

The beauty of animals, in which we all delight, is usually in form, or in colour, or in movement. Especially in the simplest animals, the beauty of form is often comparable to that of crystals; witness the marvellous architecture in flint and lime exhibited by the marine Protozoa, whose empty shells form the ooze of the great depths. In higher animals also an almost crystalline exactness of symmetry is often apparent, but we find more frequent illustration of graceful curves in form and feature, resulting in part from strenuous and healthful exercise, which moulds the body into beauty.

Not a little of the colour of animals is due to the physical nature of the surface, which is often iridescent; much, on the other hand, is due to the possession of pigments, which may either be of the nature of reserve-products, and then equivalent, let us say, to jewels, or of the nature of waste-products, and thus a literal "beauty

FIG. 3.—HUMMING-BIRDS (*Florisuga mellivora*) VISITING FLOWERS. (From Belt.)

for ashes." It is often supposed that plants excel animals in colour, but alike in the number and variety of pigments the reverse is true. Then as to movement, how much there is to admire: the bird's soaring, hovering, gliding, and diving; the monkey's gymnastics; the bat's arbitrary evolutions; the grace of the fleet stag; the dolphin gambolling in the waves; the lithe lizards which flash across the path and are gone, and the snake flowing past like a rivulet; the buoyant swimming of

fishes and all manner of aquatic animals; the lobster darting backwards with a powerful tail-stroke across the pool; the butterflies flitting like sunbeams among the flowers. But are not all the delights of form and colour and movement expressed in the songs of the birds in spring?

It seems necessary to admit that this beauty is in one sense a relative quality, varying with the surroundings and education, and even ancestral history, of those who appreciate it. A flower which seems beautiful to a bee may be unattractive to a bird, a bird may choose her mate for qualities by no means winsome to human eyes, and a dog may howl painfully at our sweet music. We call the apple-blossom and the butterfly's wings beautiful, partly because the rays of light, borne from them to our eyes, cause a pleasantly harmonious activity in our brains, partly because this awakens reminiscences of past pleasant experiences, partly for subtler reasons. Still, all healthy organisms are harmonious in form, and seldom if ever are their colours out of tone with their surroundings or with each other,—a fact which suggests the truth of the Platonic conception that a living creature is harmonious because it is possessed by a single soul, the realisation of a single idea.

The plants which seem to many eyes to have least beauty are those which have been deformed or discoloured by cultivation, or taken altogether out of their natural setting; the only ugly animals are the products of domestication and human interference on the one hand, or of disease on the other; and the ugliest things are what may be called the excretions of civilisation, which are certainly not beauty for ashes, but productions by which the hues and colours of nature have been destroyed or smothered, where the natural harmony has been forcibly put out of tune—in short, where a vicious taste has insisted on becoming inventive.

Fig. 4.—A White Peacock on the Steps at Isola Bella.
(A masterpiece of beauty.)

CHAPTER II

THE WEB OF LIFE

1. Dependence upon surroundings—2. Inter-relations of plants and animals—3. Relation of animals to the earth—4. Nutritive relations—5. More complex interactions.

In the filmy web of the spider, threads delicate but firm bind part to part, so that the whole system is made one. The quivering fly entangled in a corner betrays itself throughout the web; often it is felt rather than seen by the lurking spinner. So in the substantial fabric of the world part is bound to part. In wind and weather, or in the business of our life, we are daily made aware of results whose first conditions are remote, and chains of influence not difficult to demonstrate link man to beast, and flower to insect. The more we know of our surroundings, the more we realise the fact that nature is a vast system of linkages, that isolation is impossible.

1. **Dependence upon Surroundings.**—Every living body is built up of various arrangements of at least twelve "elements," viz. Oxygen, Hydrogen, Carbon, Nitrogen, Chlorine, Phosphorus, Sulphur, Magnesium, Calcium, Potassium, Sodium, and Iron. All these elements are spread throughout the whole world. By the magic touch of life they are built up into substances of great complexity and mutability, substances very sensitive to impulses from, or changes in, their surroundings. Thus the chemical substances known as proteids, which are absolutely essential components of living matter, are intricate compounds of Carbon, Hydrogen, Oxygen, and Nitrogen, usually with small amounts of Sulphur. As the creature lives, these and other complex substances are concerned in intricate reactions. Many substances, *e.g.* the ex-

plosive materials in a muscle, are always breaking down and being built up again from what is taken in from the outer world. The fundamental fact is that the organism is continuously dependent on its surroundings for upkeep and renewal. It is like a whirlpool in the river, but with an individuality and power of persistence all its own.

Interesting, because of its sharply defined and far-reaching significance, and because the essential mass is so nearly infinitesimal, is the part played by iron in the story of life. For food-supply we are dependent upon animals and plants, and ultimately upon plants. But these cannot produce their valuable food-stuffs without the green colouring-matter in their leaves, by help of which they are able to utilise the energy of sunshine and the carbonic acid gas of the air. But this important green pigment (though itself free from any iron) cannot be formed in the plant unless there be, as there almost always is, some iron in the soil. Thus our whole life is based on iron. And all our supplies of energy, our powers of doing work either with our own hands and brains, or by the use of animals, or through the application of steam, are traceable—if we follow them far enough—to the sun, which is thus the source of the energy in all creatures.

2. **Inter-relations of Plants and Animals.**—We often hear of the "balance of nature," a phrase of wide application, but very generally used to describe the mutual dependence of plants and animals. Every one will allow that most animals are more active than most plants, that the life of the former is on an average more intense and rapid than that of the latter. For all typical plants the materials and conditions of nutrition are found in water and salts absorbed by the roots, in carbonic acid gas absorbed by the leaves from the air, and in the energy of the sunlight which shines on the living matter through a screen of green pigment. Plants feed on very simple substances, at a low chemical level, and their most characteristic transformation of energy is that by which the kinetic energy of the sunlight is changed into the potential energy of the complex stuffs which animals eat or which

we use as fuel. But animals feed on plants or on creatures like themselves, and are thus saved the expense of building up food-stuffs from crude materials. Their most characteristic transformation of energy is that by which the power of complex chemical substances is used in locomotion and work. In so working, and eventually in dying, they form waste-products—water and carbonic acid, ammonia and nitrates, and so on—which may be again utilised by plants.

How often is the inaccurate statement repeated "that animals take in oxygen and give out carbonic acid, whereas plants take in carbonic acid and give out oxygen"! This is most misleading. It contrasts two entirely distinct processes—a breathing process in the animal with a feeding process in the plant. The edge is at once taken off the contrast when the student realises that plants and animals being both (though not equally) alive, must alike breathe. As they live there is in both an oxidation of complex organic substances, just as in the burning of a candle; in plant, in animal, in candle, oxygen passes in, as a condition of life or combustion, and carbonic acid gas passes out as a waste-product. Herein there is no difference except in degree between plant and animal. Each lives, and must therefore breathe. But the living of plants is less intense, therefore the breathing process is less marked. Moreover, in sunlight the respiration is disguised by an exactly reverse process—peculiar to plants—the feeding already noticed, by which carbonic acid gas is absorbed, its carbon retained, and part of its oxygen liberated.

There is an old-fashioned experiment which illustrates the "balance of nature." In a glass globe, half-filled with water, are placed some minute water-plants and water-animals. The vessel is then sealed. As both the plants and the animals are absorbing oxygen and liberating carbonic acid gas, it seems as if the little living world enclosed in the globe would soon end in death. But, as we have seen, the plants are able in sunlight to absorb carbonic acid and liberate oxygen, and if present in sufficient numbers will compensate both for their own

breathing and for that of animals. Thus the result within the globe need not be suffocation, but harmonious prosperity. If the minute animals ate up all the plants, they would themselves die for lack of oxygen before they had eaten up one another, while if the plants smothered all the animals they would also in turn die away. Some such contingency is apt to spoil the experiment, the end of which may be a vessel of putrid water tenanted for a long time by the very simple colourless plants known as Bacteria, and at last not even by them. Nevertheless the "vivarium" experiment is both theoretically and practically possible. Now in nature there is, indeed, no closed vivarium, for there is no isolation and there is open air, and it is an exaggeration to talk as if our life were dependent on there being a proportionate number of plants and animals in the neighbourhood. Yet the "balance of nature" is a general fact of much importance, though the economic relations of part to part over a wide area are neither rigid nor precise.

We have just mentioned the very simple plants called Bacteria. Like moulds or fungi, they depend upon other organisms for their food, being without the green colouring stuff so important in the life of most plants. These very minute Bacteria are almost omnipresent; in weakly animals—and sometimes in strong ones too—they thrive and multiply and cause death. They are our deadliest foes, but we should get rid of them more easily if we had greater love of sunlight, for this is their most potent, as well as most economical antagonist. But it is not to point out the obvious fact that a Bacterium may kill a king that we have here spoken of this class of plants; it is to acknowledge their beneficence. They are the great cleansers of the world. Animals die, and Bacteria convert their corpses into simple substances, restoring to the soil what the plants, on which the animals fed, originally absorbed through their roots. Bacteria thus complete a wide circle; they unite dead animal and living plant. For though many a plant thrives quite independently of animals on the raw materials of earth and air, others are demonstrably raising the ashes of

animals into a new life. A strange partnership between Bacteria and many kinds of leguminous plants illustrates another thread in the web of life. The Bacteria form nodules on the roots and in some obscure way they make the free nitrogen of the atmosphere available for their hosts. Thus it is that poor soil can be made rich by ploughing in crop after crop of leguminous plants. And this is only one of a score of ways in which Bacteria are bound up in the bundle of life with other creatures.

3. **Relation of Animals to the Earth.**—Bacteria are extremely minute organisms, however, and stories of their industry are apt to sound unreal. But this cannot be said of earthworms. For these can be readily seen and watched, and their trails across the damp footpath, or their castings on the grass of lawn and meadow, are familiar to us all. They are not found in very wet places, or in very dry soil, or near the spray of the sea, but otherwise they are abundantly represented in most regions of the globe. An idea of their abundance may be gained by making a nocturnal expedition with a lantern to any convenient green plot, where they may be seen in great numbers, some crawling about, others, with their tails in their holes, making slow circuits in search of leaves and vegetable débris. Darwin estimated that there are on an average 53,000 earthworms in an acre of garden ground, that 10 tons of soil per acre pass annually through their bodies, and that they bring up mould to the surface at the rate of 3 inches thickness in fifteen years. Hensen found in his garden 64 large worm-holes in 14½ square feet, and estimated the weight of the daily castings at about 2 cwt. in two and a half acres. In the open fields, however, it seems to be only about half as much. But whether we take Darwin's estimate that the earthworms of England pass annually through their bodies about 320,000,000 tons of earth, or the more moderate calculations of Hensen, or our own observations in the garden, we must allow that the soil-making and soil-improving work of these animals is momentous.

In Yorubaland, on the West African coast, earthworms

(*Siphonogaster*) somewhat different from the common *Lumbricus* are exceedingly numerous. From two separate square feet of land chosen at random, Mr. Alvan Millson collected the worm-casts of a season and found that they weighed when dry 10 lb. At this rate about 62,233 tons of subsoil would be brought in a year to the surface of each square mile, and it is also calculated that every particle of earth to the depth of two feet is brought to the surface once in 27 years. We do not wonder that the district is fertile and healthy.

Devouring the earth as they make their holes, which are often 4 or even 6 feet deep; bruising the particles in their gizzards, and thus liberating the minute elements of the soil; burying leaves and devouring them at leisure; preparing the way by their burrowing for plant roots and rain-drops, and gradually covering the surface with their castings, worms have, in the history of the habitable earth, been most important factors in progress. Ploughers before the plough, they have made the earth fruitful. It is fair, however, to acknowledge that vegetable mould sometimes forms independently of earthworms, that some other animals which burrow or which devour dead plants must also help in the process, and that the constant rain of atmospheric dust, as Richthofen has especially noted, must not be overlooked.

In 1777, Gilbert White wrote thus of the earthworms—

"The most insignificant insects and reptiles are of much more consequence and have much more influence in the economy of nature than the incurious are aware of. . . . Earthworms, though in appearance a small and despicable link in the chain of Nature yet, if lost, would make a lamentable chasm. . . . Worms seem to be the great promoters of vegetation, which would proceed but lamely without them, by boring, perforating, and loosening the soil, and rendering it pervious to rains and the fibres of plants; by drawing straws and stalks of leaves and twigs into it; and, most of all, by throwing up such infinite numbers of lumps of earth called worm-casts, which, being their excrement, is a fine manure for grain and grass. Worms probably provide new soil for hills and slopes where the rain washes the earth away; and they affect slopes probably to avoid being flooded. . . . The earth without worms would soon become cold, hard-bound, and void of fermentation, and consequently sterile. . . . These hints we think proper

to throw out, in order to set the inquisitive and discerning to work. A good monograph of worms would afford much entertainment and information at the same time, and would open a large and new field in natural history."

After a while the discerning did go to work, and Hensen published an important memoir in 1877, while Darwin's "good monograph" on the formation of vegetable mould appeared after about thirty years' observation in 1881; and now we all say with him, "It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly-organised creatures."

Prof. Drummond, while admitting the supreme importance of the work of earthworms, sought to emphasise the claims of the Termite or White Ant as an agricultural agent. This insect, which made its appearance long before the true ants, is abundant in many countries, and notably in Tropical Africa. It ravages dead wood with great rapidity. "If a man lay down to sleep with a wooden leg, it would be a heap of sawdust in the morning," while houses and decaying forest trees, furniture and fences, fall under the jaws of the hungry Termites. These fell workers are often quite blind; they are typically "cryptozoic," avoiding the light; and yet without coming out of the ground they cannot live.

"How do they solve the difficulty? They take the ground out along with them. I have seen white ants working on the top of a high tree, and yet they were underground. They took up some of the ground with them to the tree-top. They construct tunnels which run from beneath the soil up the sides of trees and posts; grain after grain is carried from beneath and mortared with a sticky secretion into a reddish sandpaper-like tube; this is rapidly extended to a great height—even of 30 feet from the ground—till some dead branch is reached. Now as many trees in a forest are thus plastered with tunnels, and as there are besides elaborate subterranean galleries and huge obelisk-like ant-hills, sometimes 10-15 feet high, it must be granted that the Termites, like the earthworms, keep the soil circulating. The earth-tubes crumble to dust, which is scattered by the wind; the rains lash the forests and soils with fury and wash off the loosened grains to swell the alluvium of a distant valley."

The influences of plants and animals on the earth are

manifold. The sea-weeds cling around the shores and lessen the shock of the breakers. The lichens eat slowly into the stones, sending their fine threads beneath the surface as thickly sometimes "as grass-roots in a meadow-land," so that the skin of the rock is gradually weathered away. On the moor the mosses form huge sponges, which mitigate floods and keep the streams flowing in days of drought. Many little plants smooth away the wrinkles on the earth's face, and adorn her with jewels; others have caught and stored the sunshine, hidden its power in strange guise in the earth, and our hearths with their smouldering peat or glowing coal are warmed by the sunlight of ancient summers. The grass which began to grow in comparatively modern (*i.e.* Tertiary) times has made the earth a fit home for flocks and herds, and protects it like a garment; the forests affect the rainfall and temper the climate, besides sheltering multitudes of living things, to some of whom every blow of the axe is a death-knell. Indeed, no plant from Bacterium to oak tree either lives or dies to itself, or is without its influence on earth and beast and man.

There are many animals besides worms which influence the earth by no means slightly. Thus, to take the minus side of the account first, we see the crayfish and their enemies the water-voles burrowing by the river banks and doing no little damage to the land, assisting in that process by which the surface of continents tends gradually to diminish. So along the shores in the harder substance of the rocks there are numerous borers, like the Pholad bivalves, whose work of disintegration is individually slight, but in sum-total great. More conspicuous, however, is the work of the beavers, who, by cutting down trees, building dams, digging canals, have cleared away forests, flooded low grounds, and changed the aspect of even large tracts of country. Then, as every one knows, there are injurious insects innumerable, whose influence on vegetation, on other animals, and on the prosperity of nations, is often disastrously great.

But, on the other hand, animals cease not to pay their filial debts. We see a multitudinous life rising like a

mist in the sea, countless millions of microscopic creatures often enclosed in beautiful shells of flint and lime; myriads of them are always being killed at the surface by vicissitudes of temperature and the like; they sink gently through the miles of water to find a grave in the abysmal ooze. The submarine volcano top, which did not reach the surface, is slowly raised by the rainfall of these countless minutiæ. Inch by inch for myriads of years, the snow-drift of dead shells forms a patient preparation for the coral island. The tiniest, hardly bigger than the wind-blown dust, form when added together the strongest foundation in the world. The vast whale skeleton falls, but melts away till only the ear-bones are left. Of the ruthless gristly shark nothing stays but teeth. The sea-butterflies (Pteropods), with their frail shells, are mightier than these, and perhaps the microscopic atomies are strongest of all. The pile slowly rises, and the exquisite fragments are cemented into a stable foundation for the future city of corals.

At length, when the height at which they can live is reached, coral germs moor themselves to the sides of the raised mound, and begin a new life on the shoulders of death. They spread in brightly coloured festoons, and have often been likened to flowers. They surround their soft bodies with strong shells of carbonate of lime, obtained by some transformation from the calcium chloride or calcium sulphate of the sea-water. Sluggish creatures they are, living in calcareous castles of indolence! In silence they spread, and crowd and smother one another in a struggle for standing-room. The dead forms, partly dissolved and cemented, become a broad and solid base for higher and higher growth. At a certain height the action of the breakers begins, great severed masses are piled up or roll down the sloping sides. Clear daylight at last is reached, the mound rises above the water. The foundations are ever broadened, as vigorously out-growing masses succumb to the brunt of the waves and tumble downwards. Within the surface-circle weathering makes a soil, and birds resting there with weary wings, or perhaps dying, leave many seeds

of plants—the beginnings of another life. The waves cast up forms of dormant life which have floated from afar, and a terrestrial fauna and flora begin. It is a strange and beautiful story, dead shells of the tenderest beauty on the rugged shoulders of the volcano; the slowly laid foundation for the reef-building polyps; at last plants and trees, the hum of insects and the song of birds, over the coral island.

4. **Nutritive Relations.**—What we may call "nutritive chains" connect many forms of life—higher animals feeding upon lower through long series, the records of which sound like the story of "The House that Jack built." On land and on the shore these series are usually short, for plants are abundant, and the carnivores feed on the vegetarians. In the open sea, where there is less vegetation, and in the great depths, where there is none, carnivore preys upon carnivore throughout long series—fish feeds upon fish, fish upon crustacean, crustacean upon worm, worm on débris. Some fishes, such as mackerel, feed mainly on the minute drifting crustaceans of the open sea (more technically, the Copepods of the Zooplankton); these in turn feed on Infusorians and Diatoms which float in countless numbers in the waters and form the stock of the sea-soup. Many animals that live on the floor of the sea depend on organic débris or detritus, part of which sinks down from the surface, while part is washed down from the shorebeds of sea-grass (Zostera) and seaweeds. This is what is meant by *the circulation of matter.*

It follows from these nutritive linkages that disturbance or weakness in one link may affect a long chain. Birds of prey and small mammals—so-called "vermin"—are killed off in order to preserve the grouse, yet this interference seems in part to defeat itself by making the survival of weak and diseased birds unnaturally easy, and epidemics of grouse-disease on this account the more prevalent. Vanity or gluttony or poverty leads men to slaughter small insect-eating birds, but the punishment falls—unluckily on the wrong shoulders—when the insects which the birds would have kept down

increase in unchecked numbers, and destroy the crops of grain and fruit. In a fuel-famine men have sometimes been forced to cut down the woods which clothe the sides of a valley, an action repented of when the rain-storms wash the hills to skeletons, when the valley is flooded and the local climate altered, and when the birds robbed of their shelter leave the district to be ravaged by caterpillar and fly. American entomologists have proved that the ravages of destructive insects may be checked by importing and fostering their natural enemies, and on the other hand, the sparrows which have established themselves in the States have in some districts driven away the titmice and other insectivorous birds—thus favouring the survival of pests.

5. **More Complex Interactions.**—The flowering plants and the higher insects have grown up throughout long ages together, in alternate influence and mutual perfecting. They now exhibit a notable degree of mutual dependence; the insects are adapted for sipping the nectar from the blossoms; the flowers are fitted for giving or receiving the fertilising golden dust or pollen which their visitors carry from plant to plant. The mouth organs of the insects have to be interpreted in relation to the flowers which they visit; while the latter show structures which have been fancifully called the "foot-prints" of the insects.

The relations of flowers and insects have formed the subject of many a fascinating volume, since Sprengel's *Newly Discovered Secret of Nature* (1793); it must suffice here to notice that, so far as we can infer from the history half hidden in the rocks, the floral world must have received a marked impulse when bees and other flower-visiting insects appeared; that for the successful propagation of flowering plants it is advantageous that pollen should be carried from one individual to another, in other words, that cross-fertilisation should be effected; and that, for the great majority of flowering plants, this is done through the agency of insects. How plants became bright in colour, fragrant in scent, rich in nectar, we cannot here discuss; the fact that they are so is

evident, while it is also certain that insects are attracted by the colour, the scent, and the sweets. Nor can there be any hesitation in drawing the inference that the flowers which attracted insects with most success, and insects which got most out of the flowers, would, *ipso facto*, succeed best in life.

No illustration of the web of life can be better than the most familiar one, in which Darwin traced the links of influence between cats and clover. If the possible seeds in the flowers of the purple clover are to become real seeds, they must be fertilised by the golden dust or pollen from some adjacent clover plants. But as this pollen is unconsciously carried from flower to flower by the humble-bees, the proposition must be granted that the more humble-bees, the better next year's clover crop. The humble-bees, however, have their enemies in the field-mice or voles, which lose no opportunity of destroying the combs; so that the fewer field-mice, the more humble-bees, and the better next year's clover crop. In the neighbourhood of villages, however, it is well known that the cats make as effective war on the field-mice as the latter do on the bees. So that next year's crop of purple clover is influenced by the number of humble-bees, which varies with the number of field-mice, that is to say, with the abundance of cats; or, to go a step farther, with the number of lonely ladies in the village. It is reported that fertile seeds of the purple clover may be formed in the absence of humble-bees, as for some time in New Zealand; in such cases there must be either self-fertilisation or some other insect-visitor as effective as the humble-bee.

Not all insects, however, are welcome visitors to plants; there are unbidden guests who do harm. To their visits, however, there are often obstacles. Stiff hairs, impassably slippery or viscid stems, moats in which the intruders drown, and other structural peculiarities, whose origin may have had no reference to insects, often justify themselves by saving the plant. Even more interesting, however, is the preservation of some acacias and other shrubs by a bodyguard of ants, which,

innocent themselves, ward off the attacks of the deadly leaf-cutters. In some cases the bodyguard and the plants are always found together, and the plants exhibit structures which look almost as if they had been made as shelters for the ants. On some of our European trees similar little homes or *domatia* constantly occur, and shelter small insects, or, it may be, mites, which do no harm to the trees, but cleanse them from injurious fungi.

FIG. 5.—ACACIA (*A. sphærocephala*), WITH HOLLOW THORNS IN WHICH ANTS FIND SHELTER. (After Schimper.)

In many ways plants are saved from the appetite of animals. The nettle has poisonous hairs; thistles, furze, and holly are covered with spines; the hawthorn has its thorns and the rose its prickles; some have repulsive odours; others contain oils, acids, ferments, and poisons which many animals dislike; the cuckoo-pint (*Arum*) is full of little crystals which make our lips smart if we nibble a leaf. In our studies of plants we endeavour to find out what these qualities primarily mean to their possessors; here we think rather of their secondary significance as protections against animals. For though snails ravage all the plants in a district except those which are repulsive, the snails are at most only the secondary factors in the evolution of the repulsive qualities.

The strange inter-relations between plants and animals are again illustrated by the carnivorous, generally insectivorous, plants. It is not our business to discuss the original or primary import of the pitchers of pitcher-plants, or of the mobile and sensitive leaves of Venus' Fly-Trap; nowadays, at any rate, insects are attracted to them, captured by them, and used. Let us take only one case, that of the common Bladderwort (*Utricularia*). Many of the leaflets of this plant, which floats in summer in the marsh pond, are modified into little bladders, so fashioned that minute "water-fleas"—which swarm in every corner of the pool—can readily enter them, but can in no wise get out again. The small entrance is guarded by a valve or door, which opens inwards, but allows no egress. The little crustaceans are attracted by some mucilage made by the leaves, or sometimes perhaps by sheer curiosity; they enter and cannot return; they die, and their débris is absorbed by the leaf.

Again, in regard to distribution, there are numerous relations between organisms. Spiny fruits like those of Jack-run-the-hedge adhere to animals, and are borne from place to place; and minute water-plants and animals are carried from one watercourse to another on the muddy feet of birds. From one clodlet from a bird's foot Darwin got eighty seeds to germinate! Not a bird can fall to the ground and die without sending a throb through a wide circle.

A conception of these chains or circles of influence is important, not only for the sake of knowledge, but also as a guide in action. Thus, to take only one instance among a hundred, it may seem a far cry from a lady's toilet-table to the African slave-trade, but when we remember the ivory backs of the brushes, and how the slaves were mainly used for transporting the tusks of elephants—a doomed race—from the interior to the coast, the riddle is read.

All over a glade or meadow of a summer morning there may be thousands of spider-webs "with dew be-diamonded," and this is an emblem of the intricacy of the

threads in the web of life. Or, is not the face of nature like the surface of a gentle stream, where hundreds of dimpling circles touch and influence one another in an infinite complexity of action and reaction beyond the ken of the wisest ?

CHAPTER III

THE STRUGGLE OF LIFE

1. Nature of the Struggle for Existence—2. Armour and Weapons—3. Different Forms of Struggle.

1. **Nature of the Struggle for Existence.**—In many cases the life of a fullgrown, well-established creature such as an oak-tree or a squirrel among its branches gives us the impression of smoothly working, stable activity, and success is certainly written on the face of much that we see in wild nature. On the other hand, it is quite plain that life is often difficult, strenuous, and hazardous; that the young creature in particular has to struggle to get and keep a foothold. The reasons for this are not far to seek. The living creature is by its very nature assertive and often insurgent. The philosopher Spinoza said that every individual thing, so far as in it lies, endeavours to persist in its own being, and this is especially true of an individual organism. It will feed and grow and multiply; it will be an agent and operate upon its surroundings. But three great sets of difficulties and limitations encompass it. First, there is the tendency to overcrowding, for most living creatures are very prolific. Second, there are the nutritive chains which have been forged in the course of ages, and there are obvious difficulties involved in the universal conjugation of the verb to eat. Third, there is the changeableness and callousness of the physical environment, which often puts living creatures on their mettle.

It is important to realise vividly the rapid multiplication of individuals which sometimes makes struggle inevitable. A single Infusorian may be the ancestor of

millions by the end of a week. A female aphis, often producing one offspring per hour for days together, might in a season be the ancestor of a progeny of atomics which would weigh down five hundred millions of stout men. The ovary of a fish like a cod may produce several millions of ova; if all these developed into young fishes, the sea would soon be solid. The unchecked multiplication of a few mice or rabbits would soon leave no standing-room on earth. When the prolific increase of numbers passes a certain limit, there may come about an extraordinarily keen struggle for existence, but in most cases the web of life has been so adjusted in the course of ages that the over-population is nipped in the bud.

When living creatures in face of limitations and difficulties do in any way thrust and parry, trying to get food when it is scarce, striving to keep their foothold when it is slippery, endeavouring to secure their well-being when it is imperilled, there in a hundred forms is the struggle for existence. It does not mean merely that there is great mortality, especially among young creatures; the central idea is that of "answering back" to difficulties. When no thrust or parry is possible, there is no struggle for existence in the strict sense. Moreover, the term is not strictly applicable to cases where some effective response or device has been discovered and established, as the indirect result of previous struggle and sifting; for when a successful answer to a particular difficulty can be given equally well by all the members of the species, the struggle for existence has been over-passed in regard to that particular point.

If we are to think accurately of what goes on in nature we must recognise that the struggle includes much more than competition to the death, that it includes a great variety of answers back. Some answers mean intenser competition, but some mean an experiment in co-operation and mutual aid. At one time the effective answer is to sharpen tooth and claw; at another time the answer is to make a safer nest for the young. The issue of the struggle may be the persistence or the extinction of a

certain type, but the actual alternative may be a longer life or an earlier death, a large and successful family or a small and miserable one. The struggle is often keen, but it is often accurately described as an endeavour after well-being. There is very little in nature that can be compared to human warfare; there is nothing to justify such a libel as comparing nature to "a continual free-fight" or to "a dismal cockpit." One naturalist says

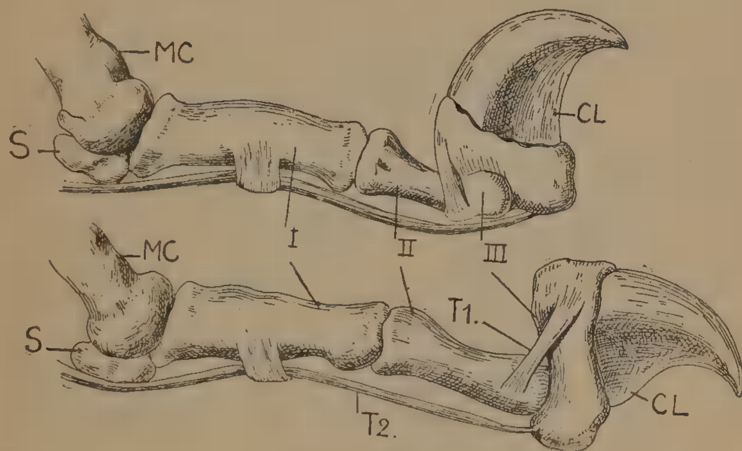


FIG. 6.—CLAWS.

The claw (*CL*) of a tiger, on one of the fingers. The upper figure shows the claw partly retracted into its sheath (not shown)—an adaptation for keeping it sharp when the animal is at rest or is simply walking. In the fore-foot it is drawn back into a sheath on the *outer* side of the middle joint or phalanx (*II*). In the hind-foot it is drawn back into a sheath on the *upper* side of the middle joint. *MC*, a metacarpal or palm-bone; *S*, a sesamoid or joint bone; *I*, *II*, *III*, the three phalanges or joints of the finger; *T1*, an elastic ligament that pulls the claw back; *T2*, the tendon of a muscle that protrudes the claw. The claw corresponds to a human nail.

that all nature breathes a hymn of love, but he is an optimist under sunny southern skies; another compares nature to a huge gladiatorial show with a plethora of fighters, but he speaks as a pessimist from amid the din of individualistic human competition. Living creatures are no strangers to struggle and fear, but the struggle is sometimes outdone by sacrifice, and the fear is sometimes cast out by love.

We must be careful to remember Darwin's proviso

that he used the phrase "struggle for existence" "in a large and metaphorical sense, including the dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny." He also acknowledged the importance of mutual aid, sociability, and sympathy among animals, and clearly saw that if, in the clash that occurs when insurgent living creatures find themselves up against difficulties and limitations, one way out be an internecine competition around the platter of subsistence, another way out is to increase the flow of the milk of animal kindness. Discussing sympathy, Darwin wrote, "In however complex a manner this feeling may have originated, as it is one of high importance to all those animals which aid and defend one another, it will have been increased through natural selection; for those communities which included the greatest number of the most sympathetic members would flourish best, and rear the greatest number of offspring."

We are dwelling on this because of the very unfortunate tendency there has been to narrow Darwin's conception of "the struggle for existence," by exaggerating the occurrence of internecine competition. Thus Huxley wrote, "Life was a continuous free-fight, and beyond the limited and temporary relations of the family, the Hobbesian war of each against all was the normal state of existence." Against which Kropotkin argued circumstantially in his *Mutual Aid* (1904) showing that this "view of nature has as little claim to be taken as a scientific deduction as the opposite view of Rousseau, who saw in nature but love, peace, and harmony destroyed by the accession of man." The fact is that "the struggle for existence" is a *formula* for all the individual and experimental reactions and endeavours, shifts and struggles that organisms exhibit in the face of all manner of limitations and difficulties.

2. **Armour and Weapons.**—To feel the reality of the struggle, one has only to take a survey of the animal kingdom. Everywhere they brandish weapons or are fortified with armour. "The world," Diderot said, "is

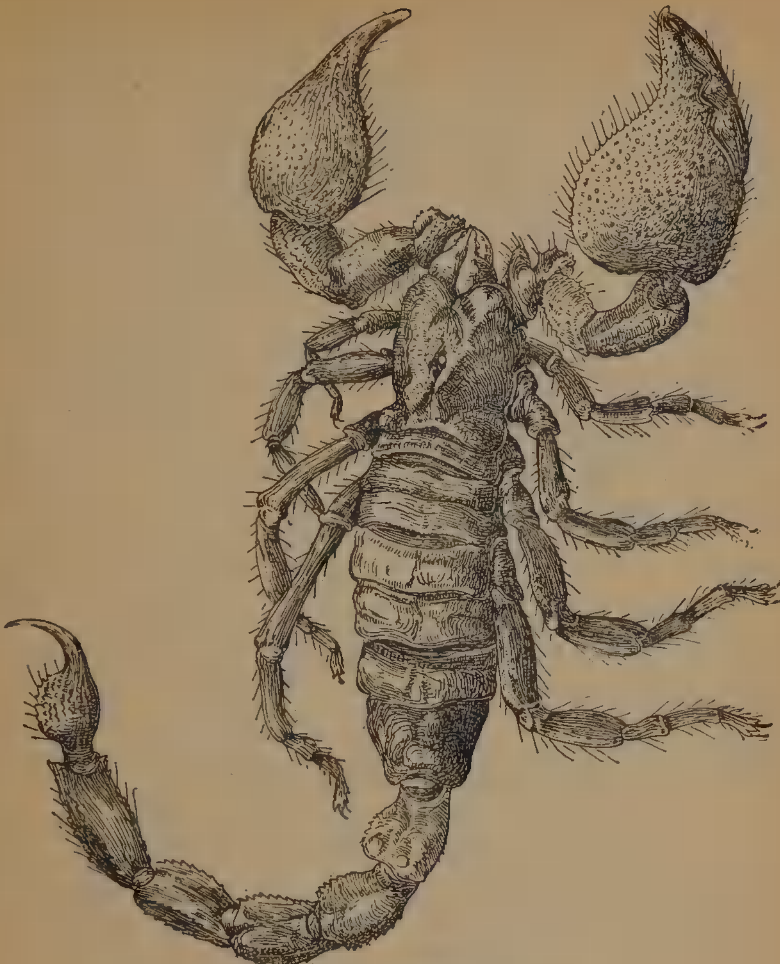


FIG. 7.—SCORPION.

A scorpion, one of the Arachnids, a fine illustration of the combination of armour and weapons. It is covered with a mail of hard chitin. It has a sting at the end of its tail, in the sharp-pointed post-anal piece called the telson (see figure of crayfish, fig. 72).

In front of the mouth are two small cheliceræ for holding an insect close to the mouth to be sucked. The second pair of appendages are the strong forceps or pedipalps, which seize insects and may hold them towards the sting. It should be noted that spiders have the same two mouth-parts, cheliceræ and pedipalps. But the poison of spiders is in the cheliceræ, and the pedipalps do not form forceps.

There are four pairs of walking legs furnished with claws. These legs arise from under the fused head and thorax, which is covered by a cephalothorax shield bearing eyes, two of which are clearly shown in the figure.

The abdomen of spiders is unsegmented; that of scorpions has twelve segments, seven forming the broad præ-abdomen, in which region there are four pairs of lung-books, and five forming the narrow post-abdomen. There are numerous setæ on the body and limbs.

the abode of the strong." Even some of the simplest animals have offensive threads, prophetic of the poisonous lassoes with which jellyfish and sea-anemones are equipped. Many worms have strong chitinoid jaws; many crustaceans have strong forceps; many insects have stings, not to speak of mouth organs like surgical instruments; spiders give poisonous bites; snails have rasping files; the cuttle-fish have strangling suckers and parrots' beaks. Among backboned animals we recall the teeth of the shark and the sword of the swordfish, the venomous fangs of serpents, the jaws of crocodiles, the beaks and talons of birds, the horns and hoofs and canines of mammals. Now we do not say that these and a hundred other weapons were from their first appearance weapons, indeed we know that most of them were not. But they are weapons now, and just as we would conclude that there was considerable struggle in a community where every man bore a revolver, we must draw a similar inference from the offensive equipment of animals. It appears to us, however, that the struggle for existence in the strict sense is not illustrated by what is now part of the every-day routine of all the members of a species and is exhibited uniformly by all, but only by individual and experimental "answers back" to some special pressure of surrounding limitations and difficulties.

As to armoured beasts, we remember that shells of lime or flint occur in many of the simplest animals, that most sponges are so rich in spicules that they are too gritty to be pleasant eating, that corals are polyps within shells of lime, that many worms live in tubes, that the members of the starfish class are in varying degrees lime-clad, that crustaceans and insects are emphatically armoured animals, and that the majority of molluscs live in shells. So among backboned animals, how thoroughly bucklered were the fishes of the Old Red Sandstone against hardly less effective teeth, how securely the sturgeon swims with its coat of bony mail! Amphibians are mostly weaponless and armourless, but reptiles are scaly animals *par excellence*, and the tortoise,

for instance, lives in an almost impregnable citadel. Birds soar above pursuit, and mammals are swift and strong, but among the latter the armadillos have bony shields of marvellous strength, and hedgehog and porcupine have their hair hardened into spines and quills. Now do we not say that all these structures were from the first of the nature of armour, indeed they admit of other explanations, but that they serve as armour now there can be no doubt. And just as we conclude that a man would not wear a chain shirt without due reason, so we argue from the prevalence of animal armour to the reality of struggle. But again the struggle for existence in the technical sense does not seem to us to be illustrated by the use of an equipment which has been long established and is shared by all the members of the species equally. The struggle is seen when some members use their armour in some novel and effective way.

3. **Different Forms of Struggle.**—We have said that it is of the very nature of living creatures to be self-preservative, expansive, insurgent—to react against difficulties and limitations. Hence struggle—whether for food or mates, whether for self or for others. Hunger and love solve the world's problems. Mouths have to be filled, but population tends locally and temporarily to outrun the means of subsistence, and the question "which mouths?" has to be decided—sometimes by peaceful endeavour, as in migration, sometimes with teeth clenched or ravenous. Many animals are carnivorous, and must prey upon weaker forms, which do their best to resist. Mates also have to be won, and lover may fight with lover till death is stronger than both; two fighting stags, for instance, sometimes interlocking their antlers fatally. But these struggles for food and for mates are often strivings rather than strife, nor is a recognition of the frequent keenness and fierceness of the competition inconsistent with the recognition that another mode of the struggle for existence in the technical sense is some experiment in mutual aid, sociability, and parental care. There is a third form of the struggle,—that between an animal and its changeful

surroundings. This also is a struggle without strife. Fellow competitors strive for their share of the limited means of subsistence; between foes there is incessant thrust and parry; in the courtship of mates there are many disappointed and worsted suitors; over all arc the shears of fate—a changeful physical environment which has no mercy.

An analysis of the various forms of struggle may be attempted as follows:

For Food	(*a*) Between animals of the same kind which compete for similar food and other necessaries of life—*Struggle between fellows*, *e.g.*, at one extreme, the larvæ of whelks which devour one another in their crowded cradles, and at the other end some device of self-subordination or social organisation which solves the pressing problem. (*b*) Between animals of different kinds, the one set striving to devour, the other set endeavouring to escape—*Struggle between foes*, *e.g.* between carnivores and herbivores.
For Love	(*c*) Between the rival suitors for desired mates—*Struggle between rivals in love*, *e.g.* stags, sea-lions.
For Foothold	(*d*) Between animals and changeful surroundings—*Struggle with fate*, *e.g.* the numerous endeavours that individual animals make to cope with the severity of winter; when, for instance, one squirrel collects a much larger store of food than its neighbours do.

(*a*) It is often said that the struggle between fellows of the same kind and with the same needs is keenest of all, but this is rather an assumption than an induction from facts. The widespread opinion is partly due to an *a priori* consideration of the problem, partly to that

FIG. 8.—BIRD-CATCHING SPIDER (*Mygale avicularia*) ATTACKING FINCHES. (From Bates.)

anthropomorphism which so easily besets us. We transfer to the animal world our own experience of keen competition with fellows of the same caste, and in so doing are probably unjust. Thus Mr. Grant Allen wrote:

> "The baker does not fear the competition of the butcher in the struggle for life; it is the competition of the other bakers that sometimes inexorably crushes him out of existence. . . . In this way the great enemies of the individual herbivores are not the carnivores, but the other herbivores. . . . It is not so much the battle between the tiger and the antelope, between the wolf and the bison, between the snake and the bird, that ultimately results in natural selection or survival of the fittest, as the struggle between tiger and tiger, between bison and bison, between snake and snake, between antelope and antelope. . . . *Homo homini lupus*, says the old proverb, and so, we may add, in a wider sense, *lupus lupo lupus*, also. . . . The struggle is fierce between allied kinds, and fiercest of all between individual members of the same species."

These sentences give forcible expression to a widely accepted conclusion that the struggle for existence is keenest between fellows of the same species. But the evidence is very unsatisfactory. In his paragraph summarised as "struggle for life most severe between individuals and varieties of the same species; often severe between species of the same genus," Darwin gave five illustrations: one species of swallow is said to have ousted another in North America, the missel-thrush has increased in Scotland at the expense of the song-thrush, the brown rat displaces the black rat, the small Asiatic cockroach drives its great congener before it, the hive-bee imported to Australia is rapidly exterminating the small, stingless native bee. But the cases of the rats, cockroaches, and thrushes have not survived criticism; they do not justify the conclusion drawn. And on the other hand, we know that reindeer, beavers, lemming, buffaloes and many other animals migrate when the means of subsistence are unequal to the demands of the population, and there are other peaceful devices by which animals have discovered a way out of a situation in which a life-and-death struggle might seem inevitable. Very instructive is the fact that beavers, when too numerous

in one locality, divide into two parties and migrate up and down stream. The old proverb which Grant Allen quotes, *Homo homini lupus*, is surely a self-contradictory libel; the extension of the libel to the animal world has certainly not been justified by careful induction. The big fact, we repeat, is this, that animals react against difficulties sometimes by increased intensity of competition, and sometimes by increased co-operation and sociality, and that both solutions have been justified in the past and are justified still. See Kropotkin, *Mutual Aid*, and Cresson's *L'Espèce et son Serviteur*.

(*b*) Of the struggle between foes differing widely in kind little need be said. It is very apparent, especially in wild countries. Carnivores prey upon herbivores, which sometimes unite in successful resistance. Birds of prey devour small mammals, and sometimes have to fight hard for their booty. Reptiles also have their battles—witness the combats between snake and mongoose. In many cases, however, carnivorous animals depend upon small fry; thus many birds feed on fishes, insects, and worms, and many fishes live on minute crustaceans. Where the victims are unable to make any protective reaction at all, there is no struggle. Where certain members of the species give a more effective response than others, they succeed, but they do not succeed by warring against their kin. When one of our worst enemies—a plague-germ—enters a household and kills half of the members, the survivors do not succeed in competition with their brothers and sisters, they succeed because they had constitutions able to parry the microbe.

(*c*) In a great number of cases there is between rival males a contest for the possession of the females,—a competition in which beauty and winsomeness are sometimes as important as strength. Contrast the musical competition between rival songsters with the fierce combats of the stags. Many animals are not monogamous, and this causes strife; a male seal, for instance, guards his harem with ferocity.

(*d*) Finally, physical nature is quite careless of life. Changes of medium, temperature, and moisture con-

tinually occur, and the animals flee for their lives, adapt themselves to new conditions, or perish. Cataclysms are rare, but changes are common, and all over the world we may study how vicissitude has its victims or its victors. There is a peculiar pleasure in discovering the ways in which animals circumvent the mercilessness of physical

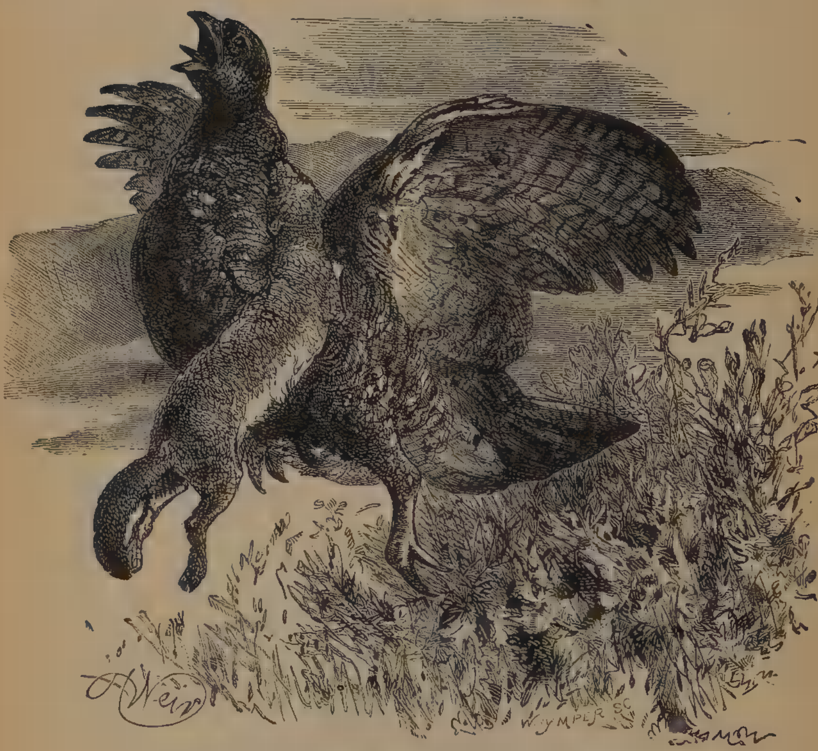


FIG. 9.—WEASEL ATTACKING A GROUSE.
(From St. John's *Wild Sports.*)

forces, and keep their foothold against wind and weather, storm and tide, drought and cold. One illustration must suffice: drought is common, pools are dried up, the inhabitants are left to perish. But often the organism draws itself together, secretes a protective sheath, which is not a shroud, and waits until the rain refreshes the pools. Not the simplest animals only, but some of comparatively

high degree, are thus able to survive desiccation. The endeavour to find the most effective way of "lying low" is part of the struggle for existence from the animal's side; the surge of the inanimate forces against a novel obstacle presented is the other side of it. The kernel-idea of the struggle for existence is the clash of life against limitations and difficulties. An elaborated and effective answer-back which all the members of the species are equally able to give has passed from the category of "struggle for existence" in the technical biological sense to the category of "adaptations," but individual improvements in the answer-back and the clash that ensues must be recognised as constituting the genuine struggle for existence in the Darwinian sense. This reiteration of our point may seem wearisome, but it is interesting to remember that Darwin himself confessed to finding the concept of "the struggle for existence" peculiarly difficult to keep in mind.

A shop which had once been used in the preparation of bone-dust was after prolonged emptiness reinstated in a new capacity. But it was soon fearfully infested with mites (*Glyciphagus*), which had been harboured in crevices in a strange state of dry dormancy. Every mite had in a sense died, but remnant cells in the body of each had clubbed together in a life-preserving union so effective that a return of prosperity was followed by a reconstitution of mites and by a plague of them. Of common little animals known as Rotifers, it is often said, and sometimes rightly, that they can survive prolonged desiccation. In a small pool on the top of a granite block, there flourished a family of these Rotifers. Now this little pool was periodically swept dry by the wind, and in the hollow there remained only a scum of dust. But when the rain returned and filled the pool, there were the Rotifers as lively as ever. What inference was more natural than that the Rotifers survived the desiccation, and lay dormant till moisture returned? But Professor Zacharias thought he would like to observe the actual revivification, and taking some of the dusty scum home, placed it under his microscope on a moist slide, and

waited results. There were the corpses of the Rotifers plain enough, but they did *not* revive even in abundant moisture. What was the explanation? The *eggs* of these Rotifers survived, they developed rapidly, they reinstated the family. And of course it is much easier to understand how single cells, as eggs are, could survive being dried up, while their much more complex parents perished. In some cases, however, it has been satisfactorily demonstrated that even the adult Rotifers may survive after being left for some time "as dry as dust." There is no doubt, moreover, that certain simple "worms," known as "paste-eels," "vinegar-eels," etc., from their frequent occurrence in such substances, can survive desiccation for many years. Repeated experiments have shown that they can lie dormant for as long as, but not longer than, fourteen years, and it is interesting to notice that the more prolonged the period of desiccation has been, the longer do these threadworms take to revive after moisture has been supplied. It seems as if the life retreated further and further, till at length it may retreat beyond recall. In regard to plants there are many similar facts, for though accounts of the germination of seeds from the mummies of the pyramids, or from the graves of the Incas, are far from satisfactory, there is no doubt that seeds of cereals and leguminous plants may retain their life in a dormant state for years, or even for tens of years.

But desiccation is only one illustration out of a score of the manner in which animals keep their foothold against fate. It must be admitted that they are often unsuccessful; the individual has often fearful odds against it. How many winged seeds out of a thousand reach a fit resting-place where they may germinate? Professor Möbius says that out of a million oyster embryos only one individual grows up, a mortality due to untoward currents and surroundings, as well as to hungry mouths. Yet the average number of thistles and oysters tends to continue, "So careful of the type she seems, so careless of the single life." Yet though the average usually remains constant, there is no use trying to ignore,

what Richard Jefferies sometimes exaggerated, that the physical fates are cruel to life. But how much wisdom have they drilled into us?

> "For life is not as idle ore,
> But iron dug from central gloom,
> And heated hot with burning fears,
> And dipt in baths of hissing tears,
> And battered by the shocks of doom
> To shape and use."

CHAPTER IV

SHIFTS FOR A LIVING

1. Insulation—2. Change of habit and habitat—3. Parasitism—4. General resemblance to surroundings—5. Variable colouring—6. Rapid change of colour—7. Special protective resemblance—8. Warning colours—9. Mimicry—10. Masking—11. Combination of advantageous qualities—12. Surrender of parts

The struggle for existence includes all the reactions and responses which living creatures, by their very nature insurgent, make to the difficulties and limitations that encompass them. Some of the answers are very effective and become established as adaptations of habit and habitat, structure and device. We may speak of them, somewhat loosely we confess, as shifts for a living.

1. **Insulation.**—Some animals have attained to temporary security through no merit of their own, but as the result of geological changes which have insulated them from their enemies. Thus, in Cretaceous times probably, the marsupials which inhabited the Australasian region were insulated. In that region they and the egg-laying Monotremes were for long the only representatives of Mammalia, and so, excepting the "native dog," some rodents and bats, and more modern imports, they still continue to be. By their insulation they were saved from that contest with stronger mammals in which all the marsupials left on the other continents were exterminated, with the exception of the American opossums and Selvas, whose shy, quiet ways have saved them. A similar geological insulation accounts for the large number of lemurs in Madagascar.

2. **Change of Habit and Habitat.**—It seems justifiable

to suppose that mammals which passed from terrestrial to more or less aquatic life, for instance beaver and polar bear, otter, seals and whales, would enjoy a period of relative immunity after the awkward time of transi-

FIG. 10.—THE LAND-CRAB OR ROBBER CRAB (*Birgus latro*).
(From a specimen.)

The animal—really a kind of hermit-crab or Pagurid—is often over a foot long. It breathes dry air by means of vascular ridges and folds in the upper part of its branchial cavity. It has also rudimentary gills. The structure of the female's abdominal limbs makes it practically certain that Birgus is descended from a shell-inhabiting ancestor, for while the abdomen as a whole is symmetrical there are three appendages used in egg-carrying which are present on the left side only. The male has no abdominal limbs. The student should compare this figure with that of the crayfish (fig. 72). Thus the last thoracic appendages are very delicate in the land-crab.

tion was over. So, too, many animals passed from the battlefield of the sea-shore to relative peace on land or in the deep-sea. In a change from open air to under-

ground life, illustrated for instance in the mole, many animals have sought and found safety, and the change seems even now in progress, as in the New Zealand parrot *Stringops*, which, having lost the power of flight, has taken to burrowing. Similarly the power of flight must have helped insects, some ancient saurians, and birds out of many a scrape, though it cannot be doubted that this discovery of a new world often brought only a temporary relief.

Taking the race of earthworms, we find that three or four genera, *e.g.* *Alma* and *Dero*, have gills, which suggests that earthworms evolved from an aquatic ancestry. And many not very distant relatives of the earthworms proper are found in the mud of rivers and ponds. Supposing, then, that earthworms discovered the possibility of a subterranean life, we can believe that they had a long Golden Age with a new world all to themselves. But in the course of time this subterranean world was invaded by centipedes and burrowing beetles, and long afterwards by the moles, so that nowadays earthworms are far from being free from persecution. The same is true of animals that hit upon the device of lying quiet during the day and coming out at night—as the earthworms have had to do. For a time, doubtless, it works very well, but when other creatures follow suit some subtler shift must be attempted. It appears that for terrestrial weaklings and slackers a cavernicolous life offers asylum, but over the door of the cave there should be a notice with the ominous words "Short Commons."

There are many extraordinary examples of animals taking to habitats quite strange to the ordinary habits of their kind. We speak of the awkwardness of a fish out of water, but many fishes are quite at home on land. The climbing perch occasionally ascends a few feet up a tree; the common equatorial shore-fish Periophthalmus clambers on to the roots of the mangroves; eels may be found making an excursion through a meadow; and one of the North-American shore "minnows," a species of Fundulus, is quite expert in jumping seawards for several yards across the sand, if it has

been left in a pool by the retiring tide. How striking again are the ways of the land-crab Birgus (see Fig. 10), which goes far up the mountains and even climbs the coco-palm for the nuts! It is hardly less remarkable that it is able to make a hole in the shell. It feeds on the pulp, uses the fibre of the nut in its burrow, and sometimes carries part of the shell about with it as a protective covering for its abdomen. Every year, however, Birgus returns to the sea-shore to breed, and its marine larvæ well illustrate the general conclusion that the young forms of a species occur in the ancestral habitat. The turtles that lay their eggs ashore illustrate the same law though the movement is in the opposite direction.

3. **Parasitism.**—From the simple Protozoa up to the beginning of the backboned series, we find illustrations of animals which have taken to a thievish existence as unbidden guests in or on other organisms. Flukes, tapeworms, and some other "worms," many crustaceans, insects, and mites, are the most notable. Few animals are free from some kind of parasite. There are various grades of parasitism; there are temporary and permanent, external and internal, very degenerate, and very slightly affected parasites. Sometimes the adults are parasitic while the young are free-living, sometimes the reverse is true; sometimes the parasite completes its life in one host, often it reaches maturity only after the host in which its youth has been passed is devoured by another. In many cases the habit was probably begun by the females, which seek shelter during the period of egg-laying; in not a few crustaceans and insects the females alone are parasitic. Most often, in all probability, hunger and the search for shelter led to the establishment of the thievish habit. Now, the advantages gained by a thoroughgoing parasite are great—safety, warmth, abundant food, in short, "complete material well-being." But there is another aspect of the case. Parasitism tends to be followed by degeneration—of appendages, food-canal, sense-organs, nervous system, and other structures, the possession and use of

which make life worth living. Moreover, though the reproductive system never degenerates, the odds are often many against an embryo reaching a fit host or attaining maturity. Thus Leuckart calculates that a tapeworm embryo has only about 1 chance in 83,000,000 of becoming a tapeworm, and one cannot be sorry that its chance is not greater. In illustration of the degeneration which is often associated with parasitism, and varies as the habit is more or less predominant, take the case of *Sacculina*—a crustacean usually ranked along with barnacles and acorn-shells. It begins its life as a minute free "nauplius," with three pairs of appendages, a short food-canal, an eye, a small brain, and some other structures characteristic of many young crustaceans. In spite of this promiseful beginning, the young *Sacculina* becomes a parasite, first within the body, and finally under the tail, of a crab. Attached by absorptive suckers to its host, and often doing no slight damage, it degenerates into an oval sac, almost without trace of its former structure, with reproductive system alone well developed. Yet the degeneration is seldom so great as this, and it is fair to state that many parasites, especially those which remain as external hangers-on, seem to be but slightly affected by their lazy thievish habit; nor can it be denied that most are well adapted to the conditions of their life. But on the whole the parasitic life tends to degeneration, and is unprogressive. Meredith writes of Nature's sifting—

> "Behold the life of ease, it drifts.
> The sharpened life commands its course:
> She winnows, winnows roughly, sifts,
> To dip her chosen in her source.
> Contention is the vital force
> Whence pluck they brain, her prize of gifts."

4. **General Resemblance to Surroundings.**—Many transparent and translucent blue animals are hardly visible in the sea; white animals, such as the polar bear, the arctic fox, and the ptarmigan in its winter plumage, are inconspicuous upon the snow; green animals, such as insects, tree-frogs, lizards, and snakes, hide among the

leaves and herbage; tawny animals harmonise with sandy soil; and the hare escapes detection among the clods. So do spotted animals such as snakes and leopards live unseen in the interrupted light of the forest, and the striped tiger is lost in the jungle. Even the eggs of birds are often well suited to the surroundings in which they are laid. There can be no doubt that this resemblance between the colour of an animal and that of its surroundings is sometimes of protective and also aggressive value in the struggle for existence, and where this is the case, natural selection would foster it, favouring with success those variations which were best adapted, and eliminating those which were conspicuous.

5. **Variable Colouring.**—Some animals, such as the ptarmigan and the mountain-hare, become white in winter, and are thereby safer and warmer. In some cases, as in the mountain-hare, the pigmented hairs seem to become white; in other cases, as in the ermine, the old hairs drop off and are replaced by white ones; sometimes the whiteness is the result of both these processes. The whiteness is directly due to the formation of gas bubbles inside the hairs or feathers. In some cases, *e.g.* Ross's lemming and the American hare (*Lepus americanus*), it has been shown experimentally that it is the cold that pulls the trigger of the change to white, but the possibility of the change, like that of other seasonal variations, doubtless depends on a constitutional peculiarity.

To several naturalists, but above all to Prof. Poulton, we are indebted for much precise information in regard to the variable colouring of many caterpillars and chrysalids, which adjust their colours to those of the surroundings. Prof. Poulton experimented with the caterpillars of the peacock butterfly (*Vanessa io*), small tortoise-shell (*Vanessa urticæ*), garden whites (*Pieris brassicæ* and *Pieris rapæ*), and many others. Caterpillars of the small tortoise-shell in black surroundings tend to become darker as pupæ; in a white environment the pupæ are lighter; in gilded boxes they tend to become golden. The surrounding colour seems to influence the caterpillar "during the twenty hours immediately preceding the last

twelve hours of the larval state," "and this is probably the true meaning of the hours during which the caterpillar rests motionless on the surface upon which it will pupate." "It appears to be certain that it is the skin of the larva which is influenced by surrounding colours during the sensitive period, and it is probable that the effects are wrought through the medium of the nervous system."

Accepting the facts that caterpillars are subtly affected by surrounding colours, so that the quiescent pupæ harmonise with their environment, and that the adjustment has often protective value, we are led to inquire into the origin of this sensitiveness. That the change of colour is not a direct result of external influence is certain, but of the physiological nature of the changes we know little more than that it must be complex. Prof. Poulton suggests that the power of producing variable colouring arose as a constitutional variation apart from the influence of the environment, that the power was fostered in the course of natural selection, and that its limits were in the same way more or less defined in adaptation to the most frequent habitat of the larvæ before and during pupation.

6. **Rapid Change of Colour.**—For ages the chamæleon has been famous for its rapid and sometimes striking changes of colour. The members of the Old World genus *Chamæleo* quickly change from green to brown or other tints, but rather in response to physical irritation and varying moods than in relation to change of situation and surrounding colours. So the American "chamæleons" (*Anolis*) change, for instance, from emerald to bronze under the influence of excitement and various kinds of light. Their sensitiveness is exquisite; "a passing cloud may cause the bright emerald to fade." Sometimes they may be thus protected, for "when on the broad green leaves of the palmetto, they are with difficulty perceived, so exactly is the colour of the leaf counterfeited. But their dark shadow is very distinct from beneath." Most of the lizards have more or less of this colour-changing power, which depends on the contrac-

tion and expansion of the pigmented living matter of cells which lie in layers in the under-skin, and are controlled by nerves. (See Fig. 11.)

In a widely different set of animals—the cuttle-fishes—the power of rapid colour-change is well illustrated. When a cuttle-fish in a tank is provoked, or when one almost stranded on the beach struggles to free itself, or, most beautifully, when a number swim together and keep time in their locomotor movements, flushes of colour spread over the body. The sight suggests the blushing of higher animals, in which nervous excitement passing from the centre along the peripheral nerves influences the blood-supply in the skin; but in colour-change the nervous thrills affect the pigment-containing cells or chromatophores, the living matter of which contracts or expands in response to stimulus. It must be allowed that the colour-change of cuttle-fish is oftenest an expression of nervous excitement, but in some cases it helps to conceal the animals.

More interesting to us at present are those cases of colour-change in which animals respond to the hues of their surroundings. This has been observed in some Amphibians, such as tree-frogs; in many fishes, such as plaice, stickleback, minnow, trout, *Gobius ruthensparri*, *Serranus*; and in not a few crustaceans. The colour of surroundings affects the fishes and frogs through the eyes, for blind plaice, trout, and frogs do not change their tint. The nervous thrill passes from eye to brain, and thence extends, not down the main path of impulse—the spinal cord—but down the sympathetic chain. If this be cut, the colour-change does not take place. The sympathetic system is connected with nerves passing from the spinal cord to the skin, and it is along these that the impulse is further transmitted. The result is the contraction or expansion of the pigment in the skin-cells. Though the path by which the nervous influence passes from the eye to the skin is somewhat circuitous, the change is often very rapid. As the resulting resemblance to surroundings is often precise, there can be no doubt that the peculiarity sometimes profits its possessors.

Profs. Gamble and Keeble have studied the extraordinary power of colour-change in the Æsop prawn (*Hippolyte varians*), which takes on the colour of its surroundings through a wide range (red, yellow, blue, orange, olive, violet, brown, green) both when young

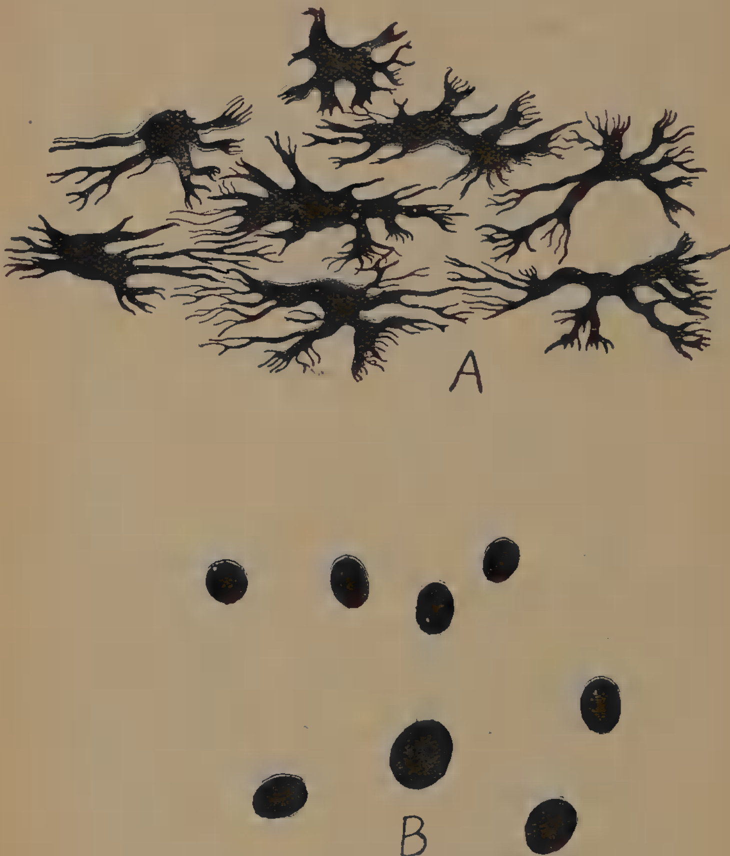


FIG. 11.—CHROMATOPHORES.

A, a group of eight amœboid pigment-cells (chromatophores) in the skin of a fish. (After Ballowitz.) They are fully expanded, sending out filamentous processes (*pseudopodia*) in all directions. A change of light may bring about their contraction, and the lower figure (*B*) shows the same group of eight cells contracted. Thus the colour changes. Black, yellow, and red chromatophores are common in fishes. The silveriness is mainly due to spangles of a waste product (*guanin*) enclosed in special cells (*iridocytes*). The fine markings on the scales often enhance the coloration, producing for physical reasons a sort of metallic or iridescent brilliance.

and when adult, and can change from one colour to another with ease. It is often difficult to detect among the brightly coloured seaweeds.

7. **Special Protective Resemblance.**—The likeness between animals and their surroundings is often very precise, and includes form as well as colour. Thus some bright butterflies, *e.g. Kallima*, are conspicuous in flight, but become precisely like brown withered leaves when they settle upon a branch and expose the under sides of their raised wings; the leaf-insects (*Phyllium*) have leaf-like wings and legs; the "walking-sticks" (Phasmidæ), with legs thrown out at all angles, resemble irregular twigs; many caterpillars (of *Geometra* moths especially), sit motionless on a branch, supported in a strained attitude by a thin thread of silk, and exactly resemble twigs; others are like bark, moss, or lichen. Among caterpillars protective resemblance is very common, and Prof. Poulton associates its frequent occurrence with the peculiarly defenceless condition of these young animals. "The body is a tube which contains fluid under pressure; a slight wound entails great loss of blood, while a moderate injury must prove fatal." "Hence larvæ are so coloured as to avoid detection or to warn of some unpleasant attribute, the object in both cases being the same—to leave the larva untouched, a touch being practically fatal." Among backboned animals we do not expect to find many examples of precise resemblance to surrounding objects; but one of the sea-horses (*Phyllopteryx eques*) is said to be exceedingly like the seaweed among which it lives. Organisms are often variable in shape and coloration, and it is theoretically conceivable that in conditions of life where the struggle for existence was keen and likewise subtle, variants in the direction of the garment of invisibility may have defined the surviving type, while variants in the direction of conspicuousness were speedily eliminated year after year, decade after decade, century after century, as they cropped up. It should be noted that some of the striking protective resemblances are little more than exaggerations of peculiarities of form and colouring which are seen in

incipient expression in other species which live in conditions where there is no special need of inconspicuousness. Another point is this, that all sorts of shapes and colorations occur among animals, and that about some of them all that we can say is "organic idiosyncrasy"! But it is the nature of the creature to seek environmental gloves to fit its particular tentative fingers, and this

FIG. 12.—LEAF-INSECT SEATED ON A BRANCH.
(From Belt.)

leads to the idea that some of the "invisible animals" may seek out the surroundings that suit them. Some clever creatures, such as spiders, may learn to hide among the lichens and on the bark which they most resemble. In certain cases it has been proved experimentally that this is done, not so much with full awareness, as in obedience to certain subtle physiological promptings.

In a few cases, doubtless to be added to, the value of

the protective resemblance has been definitely proved. Thus Cesnola tethered Mantises of the green variety on green plants and others of the brown variety on brown plants, and conversely, and found that the birds picked off the green insects on the brown background, the brown insects on the green background, but failed to detect green on green or brown on brown. This is a good instance of the experimental verification of the operation of natural selection.

8. **Warning Colours.**—While many animals are concealed by their colouring, others are made the more conspicuous. But, as the latter are often unpalatable or dangerous, Wallace suggested that the colours were

Fig. 13.—Moss Insect.
(From Belt.)

warnings, which, as Poulton says, "assist the education of enemies, enabling them to easily learn and remember the animals which are to be avoided." Expressing the same idea, Belt says, "the skunk goes leisurely along, holding up his white tail as a danger-flag for none to come within range of his nauseous artillery." So, the brightness of the venomous coral-snake (*Elaps*) is a warning; the rattlesnake, excitedly shaking its rattle, "warns an intruder of its presence"; the cobra "endeavours to terrify its enemy by the startling appearance of its expanded hood and conspicuous eye-like marks." The language in which conspicuous colours are described by many naturalists tends to exaggerate the subtlety of animals, for the intentional warning of possible moles-

ters involves rather complex ideas. Belt's description of the skunk, for instance, recalls a more familiar sight —a cat showing fight to a dog—in regard to which Mantegazza gravely tells us that the cat "bristles up her fur, and inflates herself to appear larger, and to frighten the dog who threatens her"! In our desire to be fair to the subtlety of animals, it is indeed difficult to avoid being credulous. The reflex reaction and the preparation for eventualities which we see in the cat surprised by a dog may justify itself in ways of which the cat has not any idea.

Perhaps the best illustration which Belt gives is that of a certain gaily-coloured frog:

> "In the woods around Santo Domingo there are many frogs. Some are green or brown, and imitate green or dead leaves, and live amongst foliage. Others are dull earth-coloured, and hide in holes and under logs. All these come out only at night to feed, and they are all preyed upon by snakes and birds. In contrast to these obscurely-coloured species, another little frog hops about in the daytime dressed in a bright livery of red and blue. He cannot be mistaken for any other, and his flaming vest and blue stockings show that he does not court concealment. He is very abundant in the damp wood, and I was convinced that he was uneatable so soon as I had made his acquaintance, and saw the happy sense of security with which he hopped about. I took a few specimens home with me, and tried my fowls and ducks with them, but none of them would touch them. At last, by throwing down pieces of meat, for which there was a great competition amongst them, I managed to entice a young duck into snatching up one of the little frogs. Instead of swallowing it, however, it instantly threw it out of its mouth, and went about jerking its head, as if trying to throw off some unpleasant taste."

Admirable, also, are the illustrations given by Prof. Poulton in regard to many caterpillars, such as the larva of the currant or magpie moth (*Abraxas grossulariata*), which is conspicuous with orange and black markings on a cream ground, and is refused altogether, or rejected with disgust, by the hungry enemies of other caterpillars. It has also been observed that some brightly coloured marine animals, *e.g.* certain Nudibranchs, are left by some fishes severely alone, and where unpalatability can

be proved on the one hand and a colour-sense on the other, we may speak of "warning colours."

The general conclusion seems fairly certain that the conspicuousness of many unpalatable or noxious animals is imprinted on the memory of their enemies, who, after paying some premiums to experience, learn to leave animals with "warning colours" alone. It will be interesting to discover how far the bright colour, the nauseous taste, the poisonous properties, the distasteful

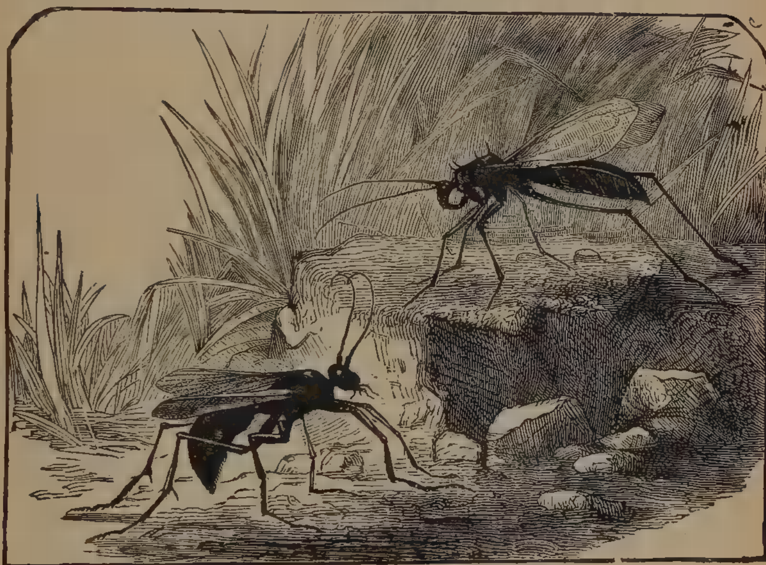


FIG. 14.—HORNET (*Priocnemis*) ABOVE, AND MIMETIC BUG (*Spiniger*) BENEATH.

(From Belt.)

odour, sometimes found associated, are physiologically related to one another, but to answer these questions we are still unprepared.

9. **Mimicry.**—The term mimicry is restricted to those cases "in which a group of animals in the same habitat, characterised by a certain type of colour and pattern, are in part specially protected to an eminent degree (the mimicked), and in part entirely without special protection (the mimickers); so that the latter live entirely upon the reputation of the former." The fact was "discovered

by Bates in Tropical America (1862), then by Wallace in Tropical Asia and Malaya (1866), and by Trimen in South Africa (1870)"; while Kirby, in 1815, referred to the advantage of a certain fly being like a bee, and of a certain spider resembling an ant.

The constant conditions of mimicry are clearly and tersely summed up by Wallace. They are:—

1. That the imitative species occur in the same area, and occupy the very same station, as the imitated.

2. That the imitators are always the more defenceless.

FIG. 15.—HUMMING-BIRD MOTH (*Macroglossa titan*), AND HUMMING-BIRD (*Lophornis gouldii*).

(From Bates.)

3. That the imitators are always less numerous in individuals.

4. That the imitators differ from the bulk of their allies.

5. That the imitation, however minute, is *external* and *visible* only, never extending to internal characters or to such as do not affect the external appearance.

Many inedible butterflies are mimicked by others quite different. Many longicorn beetles exactly mimic wasps, bees, or ants. The tiger-beetles are mimicked by more harmless insects; the common drone-fly (*Eristalis*) is like

a bee; spiders are sometimes ant-like. Mr. Bates re-

Fig. 16.—Illustrations of Masking: A Hermit Crab with Sea-anemones (after Andres), a Crab covered by a Sponge (*Suberites*), another Crab with Seaweed and Zoophyte growing on it. (In part after Carus Sterne.)

lates that he repeatedly shot humming-bird moths in mistake for humming-birds. Among Vertebrates genuine

mimicry is rare, but it is well known that some harmless snakes mimic poisonous species. Thus, the very poisonous coral-snakes (*Elaps*), which have very characteristic markings, are mimicked in different localities by several harmless forms. Similarly in regard to birds, Mr. Wallace notices that the powerful "friar-birds" (*Tropidorhynchus*) of Malaya are mimicked by the weak and timid orioles. "In each of the great islands of the Austro-Malayan region there is a distinct species of *Tropidorhynchus*, and there is always along with it an oriole that exactly mimics it." When the model is unpalatable or repulsive or dangerous, and the mimic the reverse, the mimicry is called Batesian (after Mr. Bates), but another kind of mimicry is known—called Müllerian (after Fritz Müller)—where the mimic is as unpalatable as the model. The theory in this case is that the mimicry serves as a mutual assurance, the members of the ring being the safer by all having a livery which has come to mean to their enemies "Leave me alone."

That there may be mimetic resemblance between distinct forms there can be no doubt, and the value of the resemblance has been verified; but there is sometimes a tendency to weaken the case by citing instances or using terms which have been insufficiently criticised. Thus the facts hardly justify us in saying that the larvæ of the Elephant Hawk Moth (*Chœrocampa*) "terrify their enemies by the suggestion of a cobra-like serpent"; or that the cobra, which "inspires alarm by the large eye-like 'spectacles' upon the dilated hood, offers an appropriate model for the swollen anterior end of the caterpillar, with its terrifying markings."

According to the Darwinian theory, varieties cropped up among the mimicking animals which prospered by being somewhat like the mimicked, and in the course of natural selection this resemblance was gradually increased until it became dominant and, in many cases, remarkably exact.

10. "**Masking**" is one of the most interesting ways in which animals strengthen their hold on life. It is best illustrated on the sea-shore, where there is a keen struggle

for existence and much opportunity for device. Among shore-crabs, especially, we find cases where the body is covered by adventitious disguises, so that the real nature of the creature is masked. Elsewhere, however, the same may be seen; the cases of the caddis-worms—made of sand particles, small stones, minute shells, or pieces of bark—serve at once for protection and concealment; the cocoons of various caterpillars are often masked by extrinsic fragments. The nests of birds are often well disguised with moss and lichen.

But among marine animals masking is more frequent. "Certain sea-urchins," Prof. Poulton says, "cover themselves so completely with pebbles, bits of rock and shell, that one can see nothing but a little heap of stones; and many marine molluscs have the same habits, accumulating sand upon the surface of the shell, or allowing a dense growth of Algæ to cover them."

This masking is in many cases quite involuntary. Thus the freshwater snails (*Limnæa*) may be so thickly covered with Algæ that they can hardly move, and some marine forms are unable to favour or prevent the growth of other organisms upon their shells. But how far this is from being the whole story is well known to all who are acquainted with our shore crabs. For though they also may be involuntarily masked, there is ample evidence that they sometimes disguise themselves.

The hermit-crabs are to some extent masked within their stolen shells, especially if these be covered by the Hydroid *Hydractinia* or other organisms. Various other crabs (*Stenorhynchus*, *Inachus*, *Maia*, *Dromia*, *Pisa*) are masked by the seaweeds, sponges, and zoophytes which cover their carapace. Moreover, the interest of this masking is increased by the fact observed by Mr. Bateson at Plymouth that the crabs sometimes fix the seaweeds for themselves. Mr. Bateson describes how the crab seizes a piece of weed, tears off a piece, chews the end in his mouth, and then rubs it firmly on his head and legs until it is caught by the curved hairs and fixed. "The whole proceeding is most human and purposeful. Many substances, such as hydroids, sponges, Polyzoa, and weeds of

many kinds and colours, are thus used ; but these various substances are nearly always symmetrically placed on corresponding parts of the body, and particularly long plume-like pieces are fixed on the head." Thus, as Carus Sterne says, is the story of "Birnam's walking wood" re-enacted on the sea-shore. Furthermore, a *Stenorhynchus* which has been cleaned will immediately

FIG. 17.—SACK-BEARING CATERPILLAR (*Saccophora*). (From Bates.)

begin to clothe itself again, with the same care and precision as before. Mr. Robertson of Millport often saw *Stenorhynchus longirostris*—a common crab—picking about its limbs and conveying the produce to its mouth. "If other observations confirm the view that this animal is a true vegetarian, we shall have one example at least of an independent agriculturist, who is not only superior of his lands, but carries them with him when he re-

moves." In further illustration of masking we may cite *Dromia vulgaris*, often covered with sponge; *Dromia excavata*, with compound ascidians; the Amphipod *Atylus*, with seaweed; while a species of *Dorippe* carries about a bivalve shell, or even a leaf, as a shield, and another crab cuts off the tunic of a sea-squirt and hitches it on its own shoulders.

Sometimes this masking serves as a warning or deterrent; witness that hermit-crab (*Pagurus cuanensis*) whose stolen shell is surrounded by a bright orange sponge (*Suberites domuncula*). As this sponge is full of flinty needles, has a strong odour and a disagreeable taste, we do not wonder that fishes reject it (as Prof. Garstang has shown), nor can we doubt that the hermit-crab trades on the reputation of its associate. In other cases the masking will aid in concealment and favour attack. To the associations of crabs and sea-anemones we shall afterwards refer.

11. **Combination of Advantageous Qualities.**—Prof. Poulton describes, in illustration of the combination of many methods of defence, the case of the larva of the puss-moth (*Cerura vinula*). It resembles the leaves of the poplar and willow on which it lives. When disturbed it assumes a terrifying attitude, mimetic of a Vertebrate appearance! The effect is heightened by the protrusion of two pink whips from the terminal prongs of the body, and finally the creature defends itself by squirting formic acid. Yet in spite of all this power of defence, the larva often falls a victim to ichneumon-flies. These manage to lay their eggs within the caterpillar, which by and by succumbs to the voracity of the hatched ichneumon grubs. Prof. Poulton believes that the puss-

FIG. 18.—"TERRIFYING ATTITUDE" OF THE CATERPILLAR OF *Cerura vinula*.
(From Chambers's *Encyclop.*; after Poulton.)

moth larva "has been saved from extermination by the repeated acquisition of new defensive measures. But any improvement in the means of defence has been met by the greater ingenuity or boldness of foes; and so it has come about that many of the best-protected larvæ are often those which die in the largest numbers from the attacks of enemies. The exceptional standard of defence has been only reached through the pressure of an exceptional need."

12. **Surrender of Parts.**—Among the strange life-preserving powers which animals exhibit, we must also include that of surrendering parts of the body in the panic of capture or in the struggle to escape. A rat or a stoat will sometimes gnaw off a leg to free itself from a trap. But the cases to which we now refer are not deliberate amputations, but reflex surrenders. Many lizards (such as our British "slow-worm") will readily leave their tails in their captor's grasp; crustaceans, insects, and spiders part with their limbs and scramble off maimed but safe; starfishes, brittle-stars, and feather-stars resign their arms, and the sea-cucumbers their viscera.

Among Crustacea the habit is most perfectly developed in the crabs, *e.g.* the common shore-crab (*Carcinus mænas*), and in the spiny lobster (*Palinurus*), but it is also exhibited by the crayfish (*Astacus*), the common lobster (*Homarus*), the shrimp (*Crangon*), and the prawn (*Palæmon*). In the higher crustaceans there is a gradual series leading up to the perfection of "autotomy" seen in crabs. In some cases, *e.g.* *Gammarus* and hermit-crab, the creature will nibble at an injured limb, eating it down to the base; in some cases, *e.g.* prawns, an energetic stroke of the tail is required if the self-mutilation is to be effected; in some cases, *e.g.* crayfish, the animal tugs at an injured limb. In edible-crabs (*Cancer*) and shore-crabs (*Carcinus*), the end of the limb to be thrown off must be forcibly gripped or pressed against something; in the swimming-crabs (*Portunus*) and sand-crabs (*Hyas*) this is not necessary. In the more finished cases there is a pre-determined plane of breakage at the base of the limb, a special autotomist muscle, and a

FIG. 19.—COMMON STARFISH (*Asterias rubens*), REGENERATING LOST ARMS.

It shows at the top two arms which are just beginning to be regrown. One of the original five arms has been regrown double. The madreporic plate, a perforated entrance to the water-vascular system, is seen on the disc between the two upper arms. The figure is taken from Prof. W. C. M'Intosh's atlas of the Fauna of St. Andrews Bay.

healing membrane which prevents bleeding. It is not deliberately or reflectively that the crab has learned that it is better that one member should perish than that the whole life should be lost, but the gradations of modes of self-amputation suggest that there may have been long ago much more awareness and control in the process than there is now.

Not a few insects and spiders readily surrender their legs when captured. Among Molluscs a surrender of parts has been recorded of *Harpa ventricosa*, *Doris cruenta*, *Stenopus*, some species of *Helix*, the razor-shell *Solen*; while it is well known that male cuttle-fishes sometimes part with one of their arms for special sexual purposes. A great many "worms" break very easily, and the severed parts are sometimes able to regrow the whole organism.

Among the Echinoderms the tendency to disrupt is exhibited to an extraordinary degree. Thus Prof. Preyer has shown that the seven-rayed starfish (*Asterias tenuispina*) surrenders its arms with great readiness, often giving off three or four at a time. But each ray may reproduce an entire starfish. Professor Edward Forbes tells how a specimen of *Luidia*, which he had dredged, was disappearing over the side of the boat when he caught it by one of its arms; it surrendered the arm and escaped, giving "a wink of derision" with one of its eyes. Brittle-stars (Ophiuroids) of many kinds are true to their popular name, and the Crinoids are not less disruptive. Not only are the arms readily given off, but these break into many fragments. There can be no doubt that this habit, combined with the marvellous power of regrowth which these animals possess, is of great protective value, while it is also probable, in regard to both Echinoderms and some worms, that the disruption of parts may really increase the number of individuals.

Many animals when alarmed "feign death," passing into a rigid cataleptic state, akin to the state of animal hypnosis which can be experimentally induced in some mammals, birds, reptiles, and amphibians. Many of the lower creatures, such as small crustaceans, "stop dead" when there is a sudden change in the nature of their

sensory stimulation, and it may be that this is at the root of the capacity for "feigning death" or "playing possum," which we see in many insects and crustaceans. In the state of animal hypnosis, seen, for instance, when a snake "becomes a stick," there is a sleep-like inability to move or to "right" the body when placed in an abnormal pose. There is a striking change in the tone of the muscles and a great decrease in sensitiveness to touch and to pain. It cannot be separated off from human hypnosis experimentally induced; and thus we have a long inclined plane of states—still imperfectly understood—from the sudden stoppage already referred to up to prolonged trance.

It is impossible to enumerate all the protective adaptations which animals exhibit. Let us cite but one more from Prof. Hickson's *Naturalist in North Celebes*. "I often saw advancing slowly over the sea-gardens, in parties of from four to six, a group of cuttle-fish, swimming with an even backward movement, the fringes of their mantles and their arms trembling, and their colour gradually changing to what seemed to me an almost infinite variety of hues as they passed over the various beds of the sea-bottom. Then suddenly there would be a commotion in what was previously a calm and placid scene, the striped and speckled reef fishes would be seen darting away in all directions, and of the cuttle-fishes all that remained were four or five clouds of ink in the clear water. They had thrown dust in the eyes of some small shark or voracious fish."

But in spite of all these "shifts," we must not imagine that animals are careful and troubled, for the very opposite is the case.

"They do not sweat and whine about their condition,
They do not lie awake in the dark and weep for their sins,
They do not make me sick discussing their duty to God,
Not one is dissatisfied, not one is demented
With the mania of owning things;
Not one kneels to another, nor to his kind that lived thousands
of years ago;
Not one is respectable or unhappy over the whole earth."

WALT WHITMAN.

CHAPTER V

SOCIAL LIFE OF ANIMALS

1. Partnerships—2. Co-operation and division of labour—3. Gregarious life and combined action—4. Beavers—5. Bees—6. Ants—7. Termites—8. Evolution of social life—9. Advantages of social life—10. A note on "the social organism"—11. Conclusions.

THE over-fed plant bears many leaves but its flowers are few; the artificially over-exercised rat has the normal weight-proportions of its organs greatly altered. It seems as if organ competed with organ within the body, as if one tissue might outgrow another in the living web, as if there were some struggle for existence between the individual units which form the city of cells in any of the higher animals. This idea of internal competition has been elaborated by a German biologist, Roux, in a work entitled *The Struggle of Parts within the Organism*, and it is full of suggestiveness. Yet we rightly think of an organism as a unity in which the parts are bound together in mutual helpfulness, being members one of another.

Now, just as a biologist would exaggerate greatly if he maintained that the struggle of parts was the most important fact about an organism, so would a naturalist if he maintained that there was in nature struggle only and no helpfulness.

Coherence and harmony and mutual helpfulness of parts—whether these be organs, tissues, or cells—are certainly facts in the life of individuals; we have now to ask how far the same is true of the larger life in which the many are considered as one.

1. **Partnerships.**—Animals often live together in strange

partnerships. The "beef-eater" birds (*Buphagus*) perch on cattle and extract grubs from the skin; a kind of plover (*Pluvianus ægyptius*) removes leeches and other parasites from the back of the crocodile, and perhaps "picks his teeth," as Herodotus alleged; the shark is attended by the pilot-fish (*Naucrates ductor*), who is shielded by the shark's reputation, and seems to remove parasites from his skin.

Especially among marine animals, we find many almost constant associations, the meaning of which is often obscure. Two gasteropods *Rhizochilus* and *Magilus* grow along with certain corals, some barnacles are common on whales, some sponges and polyps are always found together, without there being in any of these cases either parasitism or partnership. But when we find a little fish living contentedly inside a large sea-anemone, or the little pea-crab (*Pinnotheres*) within the horse-mussel, the probable explanation is that the fish and the crab are sheltered by their hosts and share their food. They are not known to do harm, while they derive much benefit. They illustrate "commensalism," which means eating at the same table.

But the association between crabs and sea-anemones affords a better illustration. One of the hermit-crabs of our coast (*Pagurus prideauxii*) has its borrowed shell always enveloped by a sea-anemone (*Adamsia palliata*), and *Pagurus bernhardus* may be similarly ensheathed by *Adamsia rondeletii*. Möbius describes two crabs from Mauritius which bear a sea-anemone on each claw, and in some other crabs a similar association occurs. It seems that in some cases the crab deliberately chooses its ally and plants it on its shell, and that it does not leave it behind at the period of shell-changing. Deprived of its polyp companion, one was seen to be restlessly ill at ease until it obtained another of the same kind. The use of the sea-anemone as a mask to the crab—and also perhaps as aid in attack or defence—is obvious; on the other hand, the sea-anemone is carried about by the crab and may derive food from the crumbs of its bearer's repast.

Commensalism must be distinguished from parasitism, in which the one organism feeds upon its host, though it is quite possible that a commensal might degenerate into a parasite. Quite distinct also is that intimate partnership known as symbiosis, illustrated by the union of algoid and fungoid elements to form a lichen, or by the occurrence of minute Algæ as constant internal associates and helpful partners of Radiolarians, some Cœlenterates, and a few marine worms.

2. **Co-operation and Division of Labour.**—The idea of division of labour has been for a long time familiar to men, but its biological importance was first clearly recognised by Milne-Edwards in 1827.

Among the Stinging-animals there are many animal colonies, aggregates of individuals, with a common life. These begin from a single individual and are formed by prolific budding, as a hive is formed by the prolific egg-laying of a queen-bee. The mode of reproduction is asexual in the one case, sexual in the other; the resulting individuals are physically united in the one case, psychically united in the other; but these differences are not so great as they may at first sight appear. Many masses of coral are animal colonies, but among the members or "persons," as they are technically called, division of labour is very rare; moreover, in the growth of coral the younger individuals often smother the older. In colonial zoophytes the arborescent mode of growth usually obviates crushing; and there is sometimes very marked division of labour. Thus in the colony of *Hydractinia* polyps, which is often found growing on the shells tenanted by hermit-crabs, there may be a hundred or more individuals all in organic connection. The polyps are minute tubular animals, connected at their bases, and stretching out from the surface of the shell into the still water of the pool in which the hermit-crab is resting. But among the hundred individuals there are three or four castes, the differences between which probably result from the fact that in such a large colony perfect uniformity of nutritive and other conditions is impossible. Individuals which are fundamentally and originally like

one another grow to be different, and perform different functions according to the caste to which they belong.

Many are nutritive in form like the little freshwater *Hydra*—tubular animals with an extensile body and with

FIG. 20.—AN ILLUSTRATION OF COLONY-MAKING AMONG THE PROTOZOA.

The organism (*Dendrosoma radians*) is one of the suctorial Infusorians (Acinetaria). The usual cilia or flagella are replaced by tentacle-like suckers, which grapple with passing Infusorians. By budding and budding a colony of numerous members is formed. They are connected at the base by a spreading stolon, which is fixed to a substratum. Here and there to the left may be seen oval young ones, which have a ciliated and free-swimming phase before they settle down to start a new colony.

(After Saville-Kent.)

a terminal mouth wreathed round by mobile tentacles. On these the whole nutrition of the colony depends. Beside these there are reproductive "persons," which cannot feed, being mouthless, but secure the continu-

ance of the species and give rise to embryos which start new colonies. Then there are long, lank, sensitive members, also mouthless, which serve as the sense-organs of the colony, and are of use in detecting food or danger. When danger threatens, the polyps cower down, and there are left projecting small hard spines, which some regard as a fourth class of individuals —starved, abortive members like the thorns on the hawthorn hedge. In recognising their utility to the colony as a whole we can hardly overlook the fact that their life as individuals is practically nil. They well illustrate the seamy side of division of labour.

FIG. 21.—COLONY OF *Hydractinia echinata.*

a, nutritive individuals; *b*, reproductive individuals; *c*, abortive spines; and there are also long mouthless individuals specialised in sensitiveness.

(From Chambers's *Encyclop.*; after Allman.)

Herbert Spencer and Ernst Haeckel have expressed very clearly one law of progress among those animals which form colonies. The crude form of a colony is an *aggregate* of similar individuals, the perfected colony is an *integrate* in which by division of labour greater harmony of life has resulted, and in which the whole colony is more thoroughly compacted into a unity. Among the Stinging-animals, we find some precise illustrations of such integrated colonies, especially in the Siphonophora of which the Portuguese Man-of-War (*Physalia*) is a good example. There is no doubt that these beautiful organisms are colonies of individuals, which in structure are all referable to a "medusoid" type. But the division of labour is so harmonious, and the coordination of the colony is so thorough, that the whole moves and lives as a single organism. It has become an integrate.

In many sponges part of the surplus material which abundant nutrition affords is utilised in forming buds, and one bud may fuse with another until a large composite body is built up. But it remains in most cases an aggregate rather than an integrate,—a large part may be cut off without making any difference, and there is sometimes a lack of harmonious working in the system of water-currents on which the life of the sponge depends. The higher the

degree of integration the more indispensable does each part become, and the more perfectly do the activities of the parts blend in the harmonious life of the whole. At a higher level, this is sometimes illustrated in the life of industrial organisations, communities, nations, and empires.

3. **Gregarious Life and Combined Action.**—Most mammals are in some degree gregarious. The solitary kinds are in a distinct minority. The isolated are exposed to attack, the associated are saved by the wisdom of their wisest members and by that strength which union gives. Many hoofed animals, such as deer, antelopes, goats, and elephants, live in herds, which are not mere crowds, but organised bands, with definite conventions and with a power of combined resistance which often enables them to withstand the attacks of carnivores. Marmots and prairie-dogs, whose "cities" may cover vast areas, live peaceful and prosperous lives. Monkeys furnish many illustrations of successful gregarious life. As individuals most of them are comparatively defenceless, and usually avoid coming to close quarters with their adversaries; yet in a body they are formidable, and often help one another out of scrapes. Brehm tells how he encountered a troop of baboons which defied his dogs and retreated in good order up the heights. A young one about six months old being left behind called loudly for aid. "One of the largest males, a true hero, came down again from the mountain, slowly went to the young one, coaxed him, and triumphantly led him away —the dogs being too much astonished to make an attack."

Many birds, such as rooks and swallows, nest together, and the sociality is often advantageous. Kropotkin cites from Dr. Coues an observation in regard to some little cliff-swallows which nested in a colony quite near the home of a prairie-falcon. "The little peaceful birds had no fear of their rapacious neighbour; they did not let it even approach to their colony. They immediately surrounded it and chased it, so that it had to make off at once." Of the cranes, Kropotkin notes that they are extremely "sociable and live in friendly relations, not only with their congeners, but also with most aquatic

birds." They post sentries, send scouts, have many friends and few enemies, and are very intelligent. So it is also with parrots. "The members of each band remain faithfully attached to each other, and they share in common good or bad luck." They feed together, fly together, rest together; they send scouts and post sentinels; they find protection and pleasure in combination. Like the cranes, they are very intelligent, and safe from most enemies except man.

On the other hand, some of the most successful carnivores, *e.g.* wolves, hunt in packs, and not a few birds of prey (some eagles, kites, vultures) unite to destroy their quarry. Combination for defence has its counterpart in combination for attack. In both cases the collective action is often associated with the custom of posting sentinels, who warn the rest, or of sending scouts to reconnoitre. Peculiarly interesting are those cases in which the relatively weak unite to attack the strong; thus a few kites will rob an eagle, and wagtails will persecute a sparrow-hawk. Kropotkin has noticed how the aquatic birds which crowd on the shores of lakes and seas often combine to drive off intruding birds of prey. "In the face of an exuberant life, the ideally armed robber has to be satisfied with the off-fall of that life."

Among many animals there is co-operation in labour, as well as combination for attack or defence. Brehm relates that baboons and other monkeys act in thorough concert in plundering expeditions, sending scouts, posting sentinels, and even forming a long chain for the transport of the spoil. It is said that several Hamadryad baboons will unite to turn over a large stone, sharing the booty found underneath. When the Brazilian kite has seized a prey too large for it to carry, it summons its friends; and Kropotkin cites a remarkable case in which an eagle called others to the carcase. Pelicans fish together in great companies, forming a wide half-circle facing the shore and catching the fish thus enclosed. Burial beetles unite to bury the dead mouse or bird in which the eggs are laid, and the dung-beetles help one another in rolling balls of food. But of all cases of com-

bined activity the migration of birds is at once the most familiar and the most beautiful—the gathering together, the excitement before starting, the trial flights, the reliance placed in the leaders. Migration is usually social, and is probably sometimes facilitated by social tradition.

4. **Beavers.**—That the highly socialised beavers have been exterminated in many countries where they once abounded is no argument against their sociality, for man has ingenuity enough to baffle any organisation. A family of about six members inhabits one house, and in suitable localities—secluded and rich in trees—many families congregate in a village community. The young leave the parental roof in the summer of their third year, find mates for themselves, and establish new homesteads. The community becomes overcrowded, however, and migrations take place up and down stream, the old lodges being sometimes left to the young couples. It is said, moreover, that lazy or otherwise objectionable members may be expelled from the society, and condemned to live alone. Under constraint of fear or human interference, and away from social impulse, beavers may relapse into lazy and careless habits, and in many cases each family lives its life apart; but in propitious conditions their achievements are marvellous. The burrow may rise into a constructed home, and the members of many families may combine in wood-cutting and log-rolling, and yet more markedly in constructing dams and digging canals. Make allowances for the exaggeration of enthusiastic observers, but read Mr. Lewis Morgan's stories of the evolution of a broken burrow into a comfortable lodge, varying according to the local conditions; of the adaptation of the dams against the rush of floods; of canals hundreds of feet in length—labours without reward until they are finished; of the short-cut waterways across loops of the river; and of "locks" where continuous canals are, from the nature of the ground, impossible. The Indians have invested beavers with immortality, but it is enough for us to recognise that they exhibit more sagacity than can be explained by inherited instinct; they often adapt their actions

to novel conditions in a manner which must be described as intelligent. Especially when we remember that the beaver belongs to a somewhat stupid rodent race, are we inclined to believe that it is the cleverest of its kind because the most socialised.

5. **Bees.**—Many centuries have passed since men first listened to the humming of the honey-bees, and found in the hive a symbol of the strength of unity. From Aristotle's time till now naturalists have been studying the life of bees, without exhausting either its facts or its suggestions. The society is very large and complex, yet very stable and successful. Its customs seem now like those of children at play, and now like the realised dreams of social reformers. The whole life gives one the impression of an old-established business in which all contingencies have been so often experienced that they have ceased to cause hesitation or friction. There is indeed much mortality, some apparent cruelty, and the constantly recurring adventure of migration; but though hive may war against hive, intercivic competition has virtually ceased, and the life proceeds smoothly with the harmony and effectiveness of a perfected organisation.

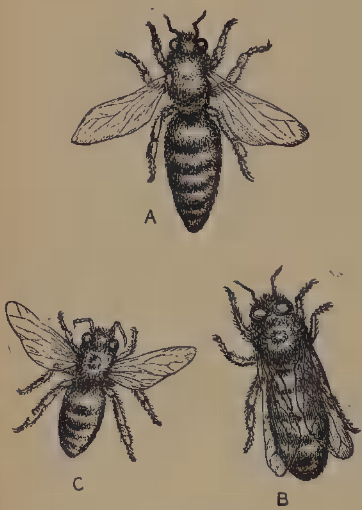


FIG. 22.—HONEY-BEE (*Apis mellifica*).
A, queen; *B*, drone; *C*, worker. (From Chambers's *Encyclop.*)

The mother-bee, whom we call a "queen"—though she is without the wits and energy of a ruler—is to this extent head of the community, that, by her prolific egg-laying, she increases or restores the population. Very sluggish in their ordinary life are the numerous males or "drones," one of whom, fleet and vigorous beyond his

fellows, will pair with a queen in her nuptial flight, himself to die soon after, saved at least from the expulsion and massacre which await the residue of the sex when supplies run short in autumn. The queen and drones are important only so far as multiplication is concerned. The sustained life of the hive is wholly in the hands of the workers, who in brains, in activity, and general equipment are greatly superior to their "queen." "The queen has lost her domestic arts, which the worker possesses in a perfection never attained by the ancestral types; while the worker has lost her maternal functions, although she still possesses the needed organs in a rudimentary state."

What a busy life is theirs, gathering nectar and pollen unwearyingly, while the sunshine lasts, neatly slipping into the secrets of the flowers or stealing their treasures by force, carrying their booty home in swift sweeping flight, often over long distances unerringly, unloading the pollen from their hind-legs and packing it into some cells of the comb, emptying out the nectar from their crop or honey-sac into store-cells, and then off again for more —such is their socialised mania for getting. But, besides these "foragers"—for the most part seniors—there are younger stay-at-home "nurses," whose labours, if less energetic, are not less essential. For it is their part to look after the grubs in their cradles, to feed them at first with a "pap" of digested nectar, and then to wean them to a diet of honey, pollen, and water; to attend the queen, guiding her movements and feeding her while she lays many eggs, sometimes 2,000 to 3,000 eggs in a day. Mr. Cheshire, in his incomparably careful book on *Bees and Beekeeping*, laughs at the "many writers who have given the echo to a mediæval fancy by stating that the queen is ever surrounded by a circle of dutiful subjects, reverently watching her movements, and liable to instant banishment upon any neglect of duty. These it was once the fashion to compare to the twelve Apostles, and, to make the ridiculous suggestion complete, their number was said to be invariably twelve!" But Mr. Cheshire's own account of the nurses' work, and of the

whole life of the hive, is more marvellous than any mediæval fancy.

We have not outlined nearly all the labours of the workers. There is the exhausting though passive labour of forming the wax which oozes out on the under-surface of the body, and then there is the marvellous comb-building, at which the bees are very neat and clever workers, though they do not deserve the reputation for mathematical insight once granted them. "Their combs," Mr. Cheshire says, "are rows of rooms unsurpassably suitable for feeding and nurturing the larvæ, for giving safety and seclusion during the mystic sleep of pupahood, for ensconcing the weary worker seeking rest, and for safely warehousing the provisions ever needed by the numerous family and by all during the winter's siege. Corridors run between, giving sufficient space for the more extensive quarters of the prospective mother, and affording every facility to the busy throng walking on the ladders the edges of their apartments supply; while the exactions of modern hygiene are fully met by air, in its native purity, sweeping past the doorway of every inhabitant of the insect city."

We shall not seek to penetrate into the more hidden mysteries of the life of bees; for instance, "how the drones have a mother but no father," or how high feeding makes the difference between a queen and a worker. An outline of the yearly life is more appropriate. From the winter's rest the surviving bees reawaken when the early flowering trees begin to blossom; the workers engage in a "spring cleaning," and the queen restores the reduced population by egg-laying. New supplies of food are brought in, new bees are born, and in early summer we see the busy life in all its energy. The pressure of increased population makes itself felt, and migration or "swarming" becomes imperative. In due time and in fair weather "the old mother departs with the superabundance of the population." Meanwhile in the parent-hive drones have been born, and several possible queens await liberation. The first to be set free has to hold her own against newcomers, or it may be to die

before one of them. The successful new queen soon becomes restless, issues forth in swift nuptial flight, is fertilised by a drone, and returns to her home to begin prolific egg-laying, and perhaps after a time to lead off another swarm. During the busy summer, when food is abundant, the lazy males are tolerated; but when their function is fulfilled, and when the supplies become scarce, they are ruthlessly put to death. "No sooner does income fall below expenditure, than their nursing sisters turn their executioners, usually by dragging them from the hive, biting at the insertion of the wing. The drones, strong for their especial work, are, after all, as tender as they are defenceless, and but little exposure and abstinence is required to terminate their being. So thorough is the war of extermination, that no age is spared; even drone eggs are devoured, the larvæ have their juices sucked and their 'remains' carried out—a fate in which the chrysalids are made to take part, the maxim for the moment being, He that will not work, neither shall he eat." This Lycurgan tragedy over, the equilibrium of the hive is more secure, and the winter comes.

The social life of hive-bees is marked by the differentiation of queens and workers, by the formation of a comb of wax, and by the accumulation of stores of pollen and nectar. It is interesting to find that it is the climax of a series of stages. Thus *Prosopis*, which lays its eggs in the pith of bramble-stems; the wood-boring *Xylophaga*; and the leaf-cutting *Megachile*, which lines its burrows with circles cut from rose leaves, are *solitary* bees, of which it must be noted that the mother-insect dies without ever seeing the brood. In various species of *Halictus*, however, though the habit is still solitary, the mother watches over the nest and survives to see the brood. The various species of humble- or bumble-bee (*Bombus*), so familiarly industrious from the spring, when the willows bear their catkins, till the autumn chill benumbs, are halfway to the hive-bees; for they live in societies of mother, drones, and workers during summer, while the sole surviving queens hibernate in solitude. From the humble-bee, moreover, we gain this hint, that

the home is centred in the cradle, for it is in a nest with honey and pollen stored around the eggs that the hive seems to have begun. The tropical species of *Melipona* and *Trigona* form permanent colonies, but with imperfect combs. They lead on to the hive-bees proper (*Apis*) in which the comb is perfected.

6. **Ants.**—Even more suggestive of our own social organisation is the Lilliputian world of the ants, who, like microscopic men, build barns and lay up stores, divide their labour and indulge in play, wage wars and make slaves. Like the bee-hive, the ant-nest includes three kinds of individuals—a queen mother or more than one, a number of short-lived males, and a crowd of workers. The queen is again pre-eminently maternal, and, if we can trust the enthusiastic observers, she is attended with loyal devotion, not without some judicious control. Farren White describes how the workers attend the queen in her perambulations: "They formed round her when she rested; some showed their regard for her by gently walking over her, others by patiently watching by her and cherishing her with their antennæ, and in every way endeavouring to testify to their affectionate attachment and generous submission." Gould ventures further, alleging that "in whatever apartment a queen condescends to be present, she commands obedience and respect, and a universal gladness spreads itself through the whole cell, which is expressed by particular acts of joy and exultation. They have a peculiar way of skipping, leaping, and standing up on their hind legs, and prancing with the others. These frolics they make use of both to congratulate each other when they meet, and to show their regard for the queen." These are wonderful lists of assumed emotions! Should an indispensable queen be desirous to quit the nest, the workers do not hesitate, it is said, to keep her by force, and to tear off her wings to secure her stay. It is certain at least that as the queens settle down to the labour of maternity, their wings are lost—perhaps in obedience to some physiological necessity. From the much greater number of the wingless workers, we are apt to forget that the

males and mothers of the social ants are winged insects; but this fact becomes impressive if in fine summer weather we are fortunate enough to see the males and young queens leaving the nest in the nuptial flight, during which fertilisation takes place. Rising in the air they glitter like sparks, pale into curling smoke, and vanish. "Sometimes the swarms of a whole district have been noticed to unite their countless myriads, and, seen at a distance, produce an effect resembling the flashing of the

Fig. 23.—Saüba Ants at Work.

To the left below, an ordinary worker; to the right, a large-headed worker; above, a subterranean worker.

(From Bates.)

Aurora Borealis; sometimes the effect is that of rainbow hues in the spray of laughing waterfalls; sometimes that of fire; sometimes that of a smoke-wreath." "Each column looks like a kind of slender network, and has a tremulous undulating motion. The noise emitted by myriads and myriads of these creatures does not exceed the hum of a single wasp. The slightest zephyr disperses them." After this midsummer day's delight of love, death awaits many, and sometimes most. The males are at best short-lived, but the surviving queens, settling down, may begin to form nests, gathering a troop of workers, or sometimes proceeding alone to found a colony.

A caste of workers (*i.e.* normally non-reproductive females) distinct from the males and queens, involves, of course, some division of labour; but there is more than this. Workers of different ages perform different tasks—foraging or housekeeping, fighting or nursing, as the case may be; and the division of labour is associated with differences of structure. Thus, in the Saüba or Umbrella Ant of Brazil (*Œcodoma cephalotes*), so well described by Bates in his *Naturalist on the Amazons*, there are three classes of workers. All the destructive labour of cutting sixpence-like disks from the leaves of trees is done by individuals with small heads, while others with enormously large heads simply walk about looking on. These "worker-majors" are not soldiers, nor is there any need for supervising officers. "I think," Bates says, "they serve, in some sort, as passive instruments of protection to the real workers. Their enormously large, hard, and indestructible heads may be of use in protecting them against the attacks of insectivorous animals. They would be, on this view, a kind of *pièces de résistance*, serving as a foil against onslaughts made on the main body of workers." The third order of workers includes very strange fellows, with the same kind of head as the worker-majors have, but "the front is clothed with hairs instead of being polished, and they have in the middle of the forehead a twin simple eye," which none of the others possess. Among the honey ants (*Myrmecocystus mexicanus*) described by Dr. M'Cook from the "Garden of the Gods" in Colorado, the division of labour is almost like a joke. The workers gather "honey" from certain galls, and discharge their spoils into the mouths of some of their stay-at-home fellows. These passive "honey-pots" store it up, till the abdomen becomes tense and round like a grape, but eventually they have even more tantalisingly to disgorge it for other members of the community. But this habit of feeding others is exhibited, as Forel has shown, by many species of ants. The hungry apply to the full for food, and get it. A refusal is said to be sometimes punished by death!

Marvellous in peace, the ants may also practise the

anti-social "art of war," sometimes against other communities of the same species, sometimes with other kinds. "Their battles," Kirby says, "have long been celebrated; and the date of them, as if it were an event of the first importance, has been formally recorded." Æneas Sylvius, after giving a very circumstantial account of one contested with great obstinacy between a large and small species on the trunk of a pear tree, gravely states, "This action was fought in the pontificate of Eugenius IV., in the presence of Nicholas Pistoriensis, an eminent lawyer, who related the whole history of the battle with the greatest fidelity." In the fray the combatants are thoroughly absorbed, yet at a little distance other workers are uninterruptedly treading their daily paths; the mêlée is intense, yet every ant seems to know those of its own party; the result of it all is often nothing. We laugh at the ants—the laugh comes back on ourselves.

In some cases an expedition has the definite end of slave-making, as is known to be true of *Formica sanguinea*—a British species, and of *Polyergus rufescens*, found on the Continent. The former captures the larvæ of *Formica fusca*, carries them home, and owns them henceforth as well-treated slaves; while the Amazon Ant (*Polyergus*) draws its supply from both *F. fusca* and *F. cunicularia*, and comes to depend very largely on its captives. While the Amazon ants can fend for themselves if they choose, there are other slave-keeping species which can neither procure food nor use it apart from their dependents. Sir John Lubbock (Lord Avebury) noted that every transition exists between bold and active baron-like marauders and enervated masters, who are virtually helpless parasites upon their slaves—a suggestive illustration of laziness outwitting itself.

Slaves somewhat painfully suggest domesticated animals, and these are also to be found among ants. For what Linnæus said long ago, that the ants went up trees to "milk their cows, the Aphides," is true. Certain species of ants tickle the plant-lice with their antennæ, and lick the juice which oozes from them; nay, more,

according to some, they inclose and tend these milch kine, and even breed them at home. Seed-harvesting and the like may be fairly called agricultural, and do not the leaf-cutting ants grow mushrooms, or at least feed on the fungi which grow on the leaves, stored, some say, with that end in view? The driver ants, "whose dread is upon every living thing," when they are on the stampede, remind us of the ancient troops of nomad hunters, though some of them are blind. Thus there are hunting, agricultural, and pastoral ants—three types, as Lubbock remarks, offering a strange analogy to the three great phases in the history of human development.

Very quaint is another habit of this "little people, so exceeding wise,"—that of keeping or tolerating guests in the home! These are mostly little beetles, and have been carefully studied by Dr. Wasmann, who distinguishes true guests (*Atemeles*, *Lomechusa*, *Claviger*) which are cared for and fed by the ants, from others (*Dinarda*, *Hœterius*, *Formicoxenus*) which are tolerated, though not treated with special friendliness, and which feed on dead ants or vegetable débris; while a third set are tolerated —like mice in our houses—only because they cannot be readily turned out. Of the genuine guests, the best known is *Atemeles*, a lively animal, constantly moving its feelers, and experimenting with everything. If one be attacked by a hostile ant, it first seeks to pacify its antagonist by antennary caresses, but if this is hopeless it emits a strong odour, which seems to narcotise the ant. These little familiars are really dependent upon their hosts, who feed them and get caresses in return. It is easy to understand the presence of pests in the ants' home, but *Atemeles* and *Lomechusa* are pets, taken away by the owners when there is a flitting, and exhibiting, as Lubbock also observes, "international relations," since they can be shifted from one nest to another, or even from species to species. It seems likely enough, as Emery suggests, that these semi-domesticated pets are moralised intruders, and, like our cats, they seem to retain some of their original traits.

We cannot linger longer over the interesting charac-

teristics of ants, though we should like to speak of their architecture, of their roads, tunnels, bridges, and covered ways; of their care for the young, and sometimes even for the disabled; of their proverbial industry, and yet of their indulgence in "sportive exercise." It would be profitable to think about the contrast between solitary ants (Mutilidæ) who have no "workers," and the complex life of a community in which there are half a million residents; or about their æsthetic sensitiveness, for they see light and hear sound for which our eyes and ears are not adapted; or about their power of recognising their fellow-citizens (even when intoxicated), and of communicating definite impressions to one another by a subtle language of touch and gesture; and, in general, with their marvellous (instinctive) power of doing things perfectly which they have never done before. Their capacities are of a type so different from ours that it is difficult for us to get mentally near them. We consider their ways with ever increasing amazement—their pertinacity, their indomitable "pluck," their tireless industry, their organic sociality. Casual observers of ants are often impressed with their futility of endeavour, and they have certainly their limitations, but careful students will agree with Sir John Lubbock (Lord Avebury), to whose observations we owe so much, that, "when we see an ant-hill, tenanted by thousands of industrious inhabitants, excavating chambers, forming tunnels, making roads, guarding their home, gathering food, feeding the young, tending their domestic animals, each one fulfilling its duties industriously and without confusion, it is difficult altogether to deny them the gift of reason." Perhaps "reason" is not the right word to use, but that ants exhibit the climax of some kind of mental power is beyond all question.

Kropotkin says that the work of ants is performed "according to the principles of voluntary mutual aid." "Mutual aid within the community, self-devotion grown into a habit, and very often self-sacrifice for the common welfare, are the rule." The marvels of their history are "the natural outcome of the mutual aid which they prac-

tise at every stage of their busy and laborious lives." To this mode of life is also due "the immense development of individual initiative." Ants are not well protected, but "their force is in mutual support and mutual confidence." "And if the ant stands at the very top of the whole class of Insects for its intellectual capacities; if its courage is only equalled by the most courageous Vertebrates, and if its brain—to use Darwin's words—'is one of the most marvellous atoms of matter in the world, perhaps more so than the brain of man,' is it not due to the fact that mutual aid has entirely taken the place of mutual struggle in the communities of ants?"

7. **Termites.**—The true ants are so supremely interesting, that the Termites or "white ants" (which are not ants at all) are apt to receive scant justice. Perhaps inferior in intelligence, they have the precedence of greater antiquity and all the interest which attaches to an old-established society. Nor is their importance less either to practical men or to speculative biologists. In 1781 Smeathman gave some account of their economy, noting that there were in every species three castes, "first, the working insects, which, for brevity, I shall generally call *labourers*; next, the fighting ones or *soldiers*, which do no kind of labour; and, last of all, the winged ones, or *perfect insects*, which are male and female, and capable of propagation."

The wingless and often blind "workers," smallest in the ant-hill, do all the work of foraging and mining, attending the royal pair and nursing the young. The soldiers, which are also wingless, are much larger than the workers, but there are relatively only a few in each hill. "They stand," Prof. Drummond says, "or promenade about as sentries, at the mouths of the tunnels. When danger threatens, in the shape of true ants, the soldier termite advances to the fight." "With a few sweeps of its scythe-like jaws it clears the ground, and while the attacking party is carrying off its dead, the builders, unconscious of the fray, quietly continue their work." At home, in the ant-hill, shut up in a chamber whose door admits workers but is much too small for the

tenants to pass out if they would, a fortunate investigator sometimes finds the royal pair. The male is sometimes even larger than the soldier, and is in many ways different, though by no means extraordinary. The queen-mother, however, is a very strange organism. She measures two to six inches, while the worker is only about a fifth of an

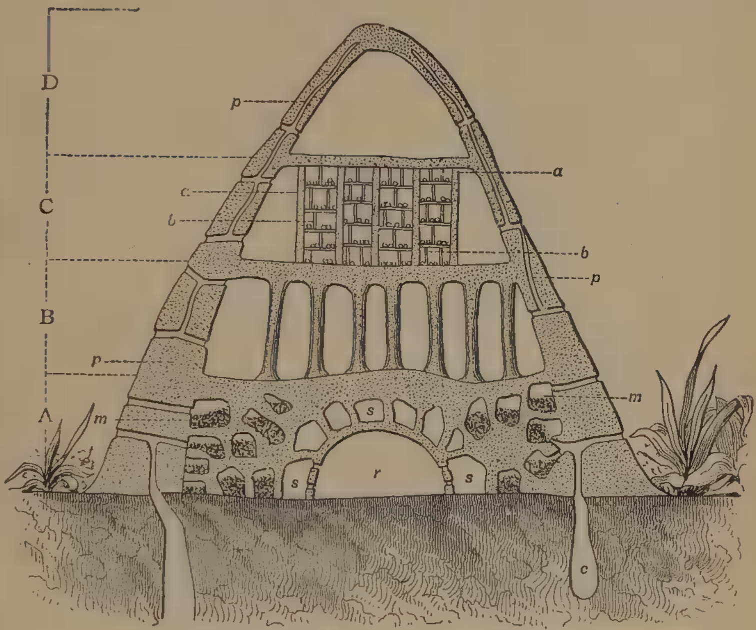


FIG. 24.—DIAGRAMMATIC SECTION OF NEST OF TERMITES. (After Houssay.)

In the walls there are winding passages (p); uppermost is a well-aired empty attic (D); the next story (C) is a nursery where the young termites are hatched on shelves (a) and (b); the next is a hall (B) supported by pillars; beneath this is a royal chamber (r) in which the king and queen are imprisoned; around this the chambers of worker-termites (s) and some store-chambers (m); excavated in the ground are holes (c) out of which the material used in making the termitary was dug. The whole structure is sometimes 10-15 feet in height.

inch in length. Like her mate, she sees, and she once had wings like his, but they have dropped off. The hind part of the body is enormously distended with eggs, and "the head bears about the same proportion to the rest of the body as does the tuft on his Glengarry bonnet to a six-foot Highlander." In her passivity and "phe-

nomenal corpulence," she is a sort of *reductio ad absurdum* of femaleness—"a large, cylindrical package, in shape like a sausage, and as white as a bolster." But have some admiration for her: she sometimes lays 60 eggs per minute, or 80,000 in a day, and continues reproducing for months. As she lays, she is assiduously fed by the nursing-workers, while the eggs are carried off to be hatched in the nurseries. At the breeding season, numerous winged males and females leave the hill and its workers in swarms, most of them simply to die, others to mate with individuals from another hill and to begin to form new colonies. When the flying termites come to earth they cast off their wings and, though not of mature age, consort together in pairs. A male and a female walk off together to found a nest. The reproductive pairing takes place long afterwards.

The plot of the story becomes more intricate when we notice Fritz Müller's observations, that "besides the winged males and females which are produced in vast numbers, and which, leaving the termitary in large swarms, may intercross with those produced in other communities, there are (in some if not all of the species) wingless males and females which never leave the termitary where they are born, and which replace the winged males or females whenever a community does not find, in due time, a true king or queen." There is no doubt as to the existence of both winged and wingless royal pairs. According to Grassi, the former fly away in spring, the others ascend the throne in summer. The complementary kings or viceroys die before winter; their mates live on, widowed but still maternal, till at least the next summer.

This replacement of royalty reminds us that hive-bees, bereft of their queen, will rear one from the indifferent grub, but the termites with which we are best acquainted seem almost always to have a reserve of reproductive members. This other difference between termites and ants or bees should be noticed, that in the latter the "workers" are highly-developed, though sterile females, while in the former the workers seem to be arrested

forms of both sexes. They are children which do not grow up.

8. **Evolution of Social Life.**—To Prof. Alfred Espinas both naturalists and sociologists are greatly indebted for his careful discussion of the social life of animals—*Des Sociétés Animales: Étude de Psychologie Comparée* (Paris, 1877):—

Co-operation, which is an essential characteristic of all society, implies, says Espinas, some degree of organic affinity. Of normal societies whose members are mutually dependent, two kinds may be distinguished—(*a*) the organically connected colonies of animals, in which there is a common nutritive life; (*b*) those associations which owe their origin and meaning to reproduction. Of the latter, some do not become more than domestic, and these are distinguished as conjugal (in which the parents alone are concerned), maternal (in which the mother is the head of the family), and paternal (in which the male becomes prominent). But higher than the pair and the family is what Espinas calls the 'peuplade,' what we usually call the society, whose bonds are, for the most part, psychical.

Let us consider this problem of the evolution of sociality. Every animal with a "body"—whether sponge or mammal—is a city of living units or cells. But there are far simpler animals than sponges. The simplest animals, which we call Protozoa, differ from all the rest in being themselves units, having no bodies, in being either "non-cellular" organisms—a mode of expression proposed by Dr. Clifford Dobell, a great authority on Protistology—or in being, as some would say, single-cell organisms, "physiologically complete in themselves."

Here is an apparent gulf. The simplest animals are units—single cells; all other animals are combinations of units—cities of cells. How is this gulf to be bridged? On the transition from a unit to a combination of units the possibility of higher life depends.

Every higher animal begins its individual life as a single cell, comparable to one of the Protozoa. This single cell, or egg-cell, divides; so do most of the Protozoa. But when a Protozoon divides, the results usually separate and live independent lives; when an egg-cell divides, the results of division cohere. Therefore, the

whole life of higher animals depends upon a coherence of units.

But how did this begin? What of the gulf between Protozoa and all the other animals which are many-celled? The gulf has been bridged, else we should not exist; but, more than that, part of the bridge is still left. There are a few of the simplest animals which form loose colonies of units, which, when they divide, remain together. Whether it was through some weakness —hindering complete division—that the transition forms between Protozoa and higher animals became strong, we do not know. All that we certainly know is that some of the simplest animals form loose colonies of units, that the gulf between them and the higher animals is thus bridged, and that the bridging depends on coherence. Our first conclusion, therefore, is, that the possibility of there being any higher animals depends, primarily, on the coherence of units.

Our next step is this: When we study sponges, or zoophytes, or most corals, or some types usually classed as "worms," we see that the habit of forming colonies is common. Every sponge is a simple sac to begin with, but it buds off others like itself, and the result is a coherent colony. A zoophyte is not one individual, but a connected colony of individuals. Throughout the colony there is one life; all the individuals have a common origin, and all are members one of another. In varying degrees of perfection the life of the whole is unified. Moreover, the unity is often increased, not diminished, by the fact that the individuals are not all alike. There is division of labour among them.

Our second conclusion is that among many animals—beginning with sponges and ending with the sea-squirts, which are acknowledged to be animals of high degree—the habit of forming colonies is common, and that these colonies, though organically continuous, illustrate the essence of society; for in them many individuals of common descent and nature are united in mutual dependence and helpfulness.

The next step towards an understanding of the social

relations of animals is very different from that in which we have recognised the habit of forming colonies. The factor which we have now to acknowledge is the love of mates. This also has its history, but we shall simply assume as a fact that among crustaceans and insects first,

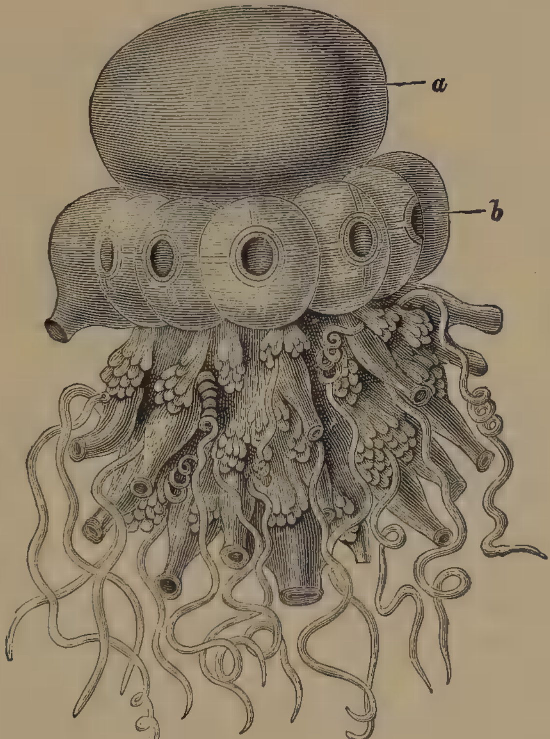


FIG. 25.—SIPHONOPHORE COLONY.
Showing the float (a), the swimming-bells (b); the nutritive, reproductive, and other members of the colony beneath.
(From the *Evolution of Sex*; after Haeckel.)

in fishes and amphibians afterwards, in reptiles too, but most conspicuously among birds and mammals, the males are attracted to the females, and in varying degrees of perfection enter into relations of mutual helpfulness. The relations and the attractions may be crude enough to begin with, but even man may learn from the heights of devotion to which their finest expressions attain.

To mere physical fondness are added subtler attractions of sight and hearing, and these are sublimed in birds and mammals to what we call love. This love of mates broadens out; it laps the family in its fold; it diffuses itself as a saturating influence through the societies of animals and of men. "Sociability," Espinas says, "is based on the friendliness of mates."

The fourth step is the evolution of the family. From monkeys and beavers and many kinds of birds, to ants and bees and diverse insects, many animals illustrate family life. There is no longer the physical continuity characteristic of the colony, but there is a growing psychical unity. It is natural that the first ties of family life should be those between mother and young, and should be strongest when the number of offspring is not very large. But even in some beetles, and more notably in certain fishes and amphibians, the males exhibit parental care and affection; while in higher animals, especially among birds, the parents often divide the labours of the family. "Children," Lucretius said, "children with their caresses broke down the haughty temper of parents."

The fifth step is the combination of families into a society, such as we find illustrated by monkeys and beavers, cranes and parrots, and in great perfection by ants. The members are less nearly related than in the family, but there may be even more unity of spirit.

We do not say that it is easy to understand how coherence of units led to the formation of a "body," how colonies became integrated and the labours of life more and more distributed, how love was evolved from apparently crude attractions between the sexes, how the love of mates was broadened into parental and filial affection, or how families well knit together formed the sure foundations of society; but it seems quite clear that these are some of the great steps in a wonderful history.

Similarly when we say that the sociality and helpfulness of animals are flowers whose roots are in kinship, we do not suppose that we are *explaining* them. We are simply tracing them back to their primitive expres-

sion. As regards the origin of that we have nothing to say; we must fall back on Aristotle's fundamental principle of evolution, that there is nothing in the end which was not also in kind in the beginning.

9. **Advantages of Social Life.**—But animals are social, not only because they love one another, but also because sociality is justified of her children. "The world is the abode of the strong," but it is also the home of the loving; "contention is the vital force," but the struggle is modified and ennobled by sociality.

(*a*) *Darwin's Position.*—Darwin observed that "the individuals which took the greatest pleasure in society would best escape various dangers; while those that cared least for their comrades, and lived solitary, would perish in greater numbers." He distinctly stipulated that the phrase "the struggle for existence" was to be used in a wide and metaphorical sense—to include all the endeavours which animals make both selfishly and unselfishly to strengthen their foothold and that of their offspring. While he emphasised the competition that often ensues when living creatures find themselves up against serious difficulties and limitations, he clearly recognised that another kind of response that pays is some experiment in mutual aid, co-operation, and parental care.

(*b*) *Kropotkin's Position.*—Against Prof. Huxley's conclusion that "Life was a continual free-fight, and beyond the limited and temporary relations of the family the Hobbesian war of each against all was the normal state of existence," let us place that of Kropotkin, to whose admirable discussion of mutual aid among animals we would acknowledge our indebtedness.

"Life in societies is no exception in the animal world. It is the rule, the law of nature, and it reaches its fullest development with the higher Vertebrates. Those species which live solitary, or in small families only, are relatively few and their numbers are limited. . . . Life in societies enables the feeblest mammals to resist, or to protect themselves from, the most terrible birds and beasts of prey; it permits longevity; it enables the

species to rear its progeny with the least waste of energy, and to maintain its numbers, albeit with a very slow birth-rate; it enables the gregarious animals to migrate in search of new abodes. Therefore, while fully admitting that force, swiftness, protective colours, cunning, and endurance of hunger and cold, which are mentioned by Darwin and Wallace as so many qualities making the individual or the species the fittest under certain circumstances, we maintain that under *any* circumstances sociability is the greatest advantage in the struggle for life. . . . The fittest are thus the most sociable animals, and sociability appears as the chief factor of evolution, both directly, by securing the well-being of the species while diminishing the waste of energy, and indirectly by favouring the growth of intelligence. . . . Therefore combine—practise mutual aid! That is the surest means for giving to each and to all the greatest safety, the best guarantee of existence and progress—bodily, intellectual, and moral. That is what nature teaches us."

10. A Note on "The Social Organism."—Herbert Spencer insisted on regarding a human societary form as a "social organism," and the metaphor is not only suggestive but convenient—suggestive because it is profitable to biologist and sociologist alike to follow out the analogies between an organism and a society, convenient because there is among organisms—in aggregates like sponges, in perfected integrates like birds—a variety comparable to the diverse grades of society.

It may be questioned, however, whether we need any other designation for society than the word society supplies, and whether the biological metaphor, with physical associations still clinging to it, is not more illusory than helpful. For the true analogy is not between society and an individual organism, but between human society and those incipient societies which were before man was. Human society is, or ought to be, an integrate—a spiritual integrate—of organisms, of which the bee-hive and the ants' nest, the community of beavers and the company of monkeys, are like far-off prophecies. And in these, as in our own societies, the modern conception

of heredity leads us to recognise that there is a very real unity even between members physically discontinuous.

The peculiarity of human society, as distinguished from animal societies, depends mainly on the fact that man is a social person, and knows himself as such. Man is the realisation of antecedent societies, and it is man's realisation of himself as a social person which makes human society what it is, and gives us a promise of what it will be. As biologists, and perhaps as philosophers, we are led to conclude that man is determined by that whole of which he is a part, and yet that his life is social freedom; that society is the means of his development, and at the same time its end; that man has to some extent realised himself in society, and that society has been to some extent realised in man.

11. **Conclusions.**—The facts lead us to agree with Kropotkin that "sociability is as much a law of nature as mutual struggle"; with Espinas that "Le milieu social est la condition nécessaire de la conservation et du renouvellement de la vie"; and with Rousseau that "man did not make society, but society made man."

CHAPTER VI

THE DOMESTIC LIFE OF ANIMALS

1. The love of mates—2. Love and care for offspring.

Winter in our northern climate sets a spell upon life. The migrant birds escape from it, but most living things have to remain spell-bound, some hiding with the supreme patience of animals, others slumbering peacefully, others in a state of "latent life" stranger than death. But within the hard rind of the trees, or lapped round by bud scales, or imprisoned within the husks of buried seeds, the life of plants is ready to spring forth when the south wind blows; beneath the snow lie the caterpillars of summer butterflies, the frogs are waiting in the mud of the pond, the hedgehog curled up sleeps soundly, and everywhere, under the seeming death, life rests until the spring. "For the coming of Ormuzd, the Light and Life Bringer, the leaf slept folded, the butterfly was hidden, the germ concealed, while the sun swept upwards towards Aries."

But when spring does come, heralded by returning migrants—swallows and cuckoos among the rest—how marvellous is the reawakening! The buds swell and burst, the corn sends up its light green shoots, the primrose and celandine are in blossom, the mother humble-bee comes out from her hiding-place and booms towards the willow catkins, the frogs croak and pair, none the worse of their fast, the rooks caw noisily, and the cooing of the dove is heard from the wood. Then, as the pale flowers are succeeded by those of brighter tints, as the snowy hawthorn gives place to the laburnum's "dropping wells of fire" and the bloom of the lilac, the butterflies

FIG. 26.—BOWER-BIRDS (*Chlamydodera*) AND THEIR BOWER.
(From Darwin; after Brehm.)

flit in the sunshine, the chorus of birds grows stronger, and the lambs bleat in the valley. Temperature rises, colours brighten, life becomes strong and lusty, and the earth is filled with love.

1. **The Love of Mates.**—In human life one of the most complex musical chords is the love of mates, in the higher forms of which we distinguish three notes—physical, emotional, and intellectual attraction. The love of animals, however, we can only roughly gauge by analogy; our knowledge is not sure enough to appreciate it justly, though we know beyond any doubt that in many the physical fondness of one sex for another is sublimed by the addition of subtler emotional sympathies. Among mammals, which frequently pair in spring, the males are often transformed by passion, the "timid" hare becomes an excited combatant with his rivals, while in the beasts of prey love often proves itself stronger than hunger. There is much ferocity in mammalian courtship—savage jealousy of rivals, mortal struggles between them, and success in wooing to the strongest. In many cases the love-making is like a storm—violent but passing. The animals pair and separate—the females to motherhood, the males to their ordinary life. A few, like some small antelopes, seem to remain as mates from year to year; many monkeys are said to be monogamous; but this is not the way of the majority.

Birds are more emotional than mammals, and their love-making is more refined. The males are almost always more decorative than their mates, and excel in the power of song. They may sing, it is true, from sheer gladness of heart, from a genuine joy of life, and their lay rises "like the sap in the bough"; but the main motive of their music is certainly love. It may not always be music to us, but it is sweet to the ears for which it is meant—to which in many tones the song says ever "Hither, my love! Here I am! Here!" Nor do the male birds woo by singing alone, but by love dances and by fluttering displays of their bright plumage; with flowers, bright pods, and shining shells, the bower-birds decorate tents of love for their honeymoon. The

mammals woo chiefly by force; the birds are often moved to love by beauty, and mates often live in prolonged partnership with mutual delight and helpfulness. Sixty years before Darwin elaborated his theory of sexual selection, according to which males have grown more attractive because the most captivating suitors were most successful in love, the ornithologist Bechstein noted how the female canary or finch would choose the best singer among a crowd of suitors; and it is still a tenable theory that the female's choice of the most musical or the most handsome or the most exciting has been a factor in progress. Wallace, on the contrary, maintained that the females are plainly dressed because of the elimination of the conspicuous during incubation, and denied that there is effective selection in courtship. It may be that masculine characteristics, arising to begin with as germinal variations in males, are congruent with maleness, and do not emerge in individual development except in what one may call a male soil. And similarly for feminine peculiarities, which are usually more negative.

Compared with the lion's thunder, the elephant's trumpeting, or the stag's resonant bass, and the might which lies behind these, or with the warble of the nightingale, the carol of the thrush, the lark's blithe lay, or the mocking-bird's nocturne, and the emotional wealth which these express, the challenges and calls of love among other classes of animals are apt to seem lacking in force or beauty. But our human judgment affords no sure criterion. The frogs and toads, which lead on an average a somewhat sluggish life, wake up at pairing time, and croak according to their strength. Vocal powers are sometimes confined to the males, which may be furnished with two resonating sacs at the back of the mouth. It is a very interesting fact that the voices of the different species of frogs and toads are quite characteristic.

Of the mating of fishes we know little, but there are some well-known cases alike of display and of tournament. The stickleback fights with his rivals, leads his

mate to the nest by captivating wiles, dances round her in a frenzy, and afterwards guards the eggs with jealous care.

FIG. 27.—MALE AND FEMALE BIRD OF PARADISE (*Paradisea minor*). The male has highly decorative, brilliantly coloured plumage. That of the female is simple and relatively plain.

(From *Evolution of Sex*; after Catalogue of Dresden Museum.)

Among insects the love-play is again very lively. Like birds, many of these active animals are very beautiful in colour and form, especially in the male sex, and a display of charms has often been noticed. Like birds, though in a different fashion, some of them are musical, using their hard legs and wing-edges as instruments. The crickets chirp merrily, the cicadas "sing," and the death-watch taps at the door of his mate.

In the summer night, when colours are put out by the darkness, the glow-worm shines brightly on the mossy bank. In the British species (*Lampyris noctiluca*) the winged male and the wingless female are both luminous; the latter indeed excels in brightness, while her mate has larger eyes. Whatever the phosphorescence may mean to the constitution of the insect, it is certainly a love-signal between the sexes. But we know most about the Italian glow-worm (*Luciola italica*), of whose behaviour we have a lively picture—thanks to Professor Emery's nocturnal observations in the meadows around Bologna. The females sit among the grass; the males fly about in search of them. When a female catches sight of the flashes of an approaching male, she allows her splendour to shine. He sees the female's signal, and is swiftly beside her, circling round like a dancing elf. But one suitor is not enough. The female attracts a levée. In polite rivalry her devotees form a circle and await the coquette's choice. In the two sexes, Emery says, the colour of the light is identical, and the intensity seems much the same, though the love-light of the female is more restricted. The most noteworthy difference is that the luminous rhythm of the male is more rapid, with briefer flashes; while that of the female is more prolonged, with longer intervals, and more tremulous—illumined symbols of the contrast between the sexes.

While recognising the genuinely beautiful love-making of most birds, we did not ignore that the courtship of most mammals is somewhat rough. So, after admiring the love-dances of many butterflies, the merry songs of the grasshoppers, and the flashing signals of the glow-insects, it is just that we should turn to the strange

courtship of spiders, which is less ideal. We have selected some illustrations from an account of the courtship of spiders by George W. and Elizabeth G. Peckham.

According to these observers, "there is no evidence that the male spiders possess greater vital activity; on the contrary, it is

FIG. 28.—A SPECIES OF GELASIMUS.
(Drawn from a specimen.)

This genus of crabs is widely represented on tropical shores. The male is marked by an enormous exaggeration of one of the forceps or chelæ, usually the right. In the female the two chelæ are small and of the same size.

The exaggerated forceps has probably several uses. It may be used by the male to close the door of the burrow when he and his mate are safely within. It may be used in fighting with other males. Alcock observed in Indian Ocean species that the large chela is bright red and that the males brandish it about before the females as if to excite their admiration. The long stalks of the eyes will be noticed.

the female that is the more active and pugnacious of the two. There is no relation in either sex between development of colour and activity. The Lycosidæ, which are the most active of all spiders, have the least colour-development, while the sedentary orb-weavers show the most brilliant hues. In the numerous cases where the male differs from the female by brighter colours and ornamental appendages, these adornments are not only so placed

as to be in full view of the female during courtship, but the attitudes and antics of the male spider at that time are actually such as to display them to the fullest extent possible. The fact that in the Attidæ the males vie with each other in making an elaborate display, not only of their grace and agility, but also of their beauty, before the females, and that the females, after attentively watching the dances and tournaments which have been executed for their gratification, select for their mates the males that they find most pleasing, points strongly to the conclusion that the great differences in colour and in ornament between these spiders are the result of sexual selection."

These conclusions support Darwin's position that the female's choice is a great factor in evolving attractiveness, and are against

FIG. 29.—TWO MALE SPIDERS (*Habrocestum splendens* TO THE LEFT, AND *Astia vittata* TO THE RIGHT) DISPLAYING THEMSELVES BEFORE THEIR MATES.

(After G. W. and E. G. Peckham.)

Wallace's contention that bright colours express greater vitality, and that the females are less brilliant because enemies eliminate the conspicuous. It is quite likely that Darwin's view is true in some cases (*e.g.* these spiders), and Wallace's conclusion true in others (*e.g.* birds and butterflies), or that both may be true in many cases; while the fact that the males of these spiders are always more brilliant than their mates suggests again that the brilliancy is wrapped up along with the mystery of maleness, which it is not sufficient to define merely as superabundant vitality, or as greater activity, but rather as a tendency towards a relative increase of destructive or disruptive vital changes over those which are constructive or conservative. But the problem is very complex, and dogmatic conclusions are premature. We need to know the chemical nature and history of the pigments to which the colour is due; we need to have an approximate balance-sheet of the income and expenditure of the two sexes. Enough of this,

however; let us return to the pictures. We talk about romance—listen to these patient observers:

"On reaching the country we found that the males of *Saitis pulex* were mature and were waiting for the females, as is the way with both spiders and insects. In this species there is but little difference between the sexes. On May 24th we found a mature female and placed her in one of the larger boxes, and the next day we put a male in with her. He saw her as she stood perfectly still, twelve inches away. The glance seemed to excite him, and he at once moved toward her. When some four inches from her he stood still, and then began the most remarkable performances that an amorous male could offer to an admiring female. She eyed

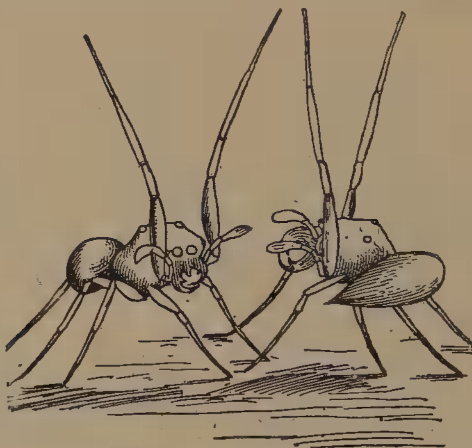


FIG. 30.—TWO MALE SPIDERS (*Zygoballus bettini*) FIGHTING. (After G. W. and E. G. Peckham.)

him eagerly, changing her position from time to time, so that he might always be in view. He, raising his whole body on one side by straightening out the legs, and lowering it on the other by folding the first two pairs of legs up and under, leaned so far over as to be in danger of losing his balance, which he only maintained by sidling rapidly toward the lowered side. The palpus, too, on this side was turned back to correspond to the direction of the legs nearest it. He moved in a semicircle of about two inches, and then instantly reversed the position of the legs and circled in the opposite direction, gradually approaching nearer and nearer to the female. Now she dashes toward him, while he, raising his first pair of legs, extends them upward and forward as if to hold her off, but withal slowly retreats. Again and again he circles from side to side, she gazing toward him in a softer mood, evidently admiring the grace of his antics. This is repeated until we have counted one hundred and eleven circles made by the ardent little male. Now he ap-

proaches nearer and nearer, and when almost within reach whirls madly around and around her, she joining and whirling with him in a giddy maze. Again he falls back, and resumes his semicircular motions with his body tilted over; she, all excitement,

FIG. 31.—MALE ARGUS PHEASANT DISPLAYING ITS PLUMAGE. (From Darwin.)

lowers her head and raises her body, so that it is almost vertical. Both draw nearer, she moves slowly under him, he crawling over her head, and the mating is accomplished." The males are quarrelsome and fight with one another; but after watching "hundreds of seemingly terrible battles" between the males of twelve different species, the observers were forced to the conclusion that "they are all sham affairs gotten up for the purpose of displaying before the females, who commonly stand by interested spectators." "It seemed cruel sport at first to put eight or ten males (of *Dendryphantes capitatus*) into a box to see them fight, but it was soon apparent that they were very prudent little fellows, and were fully conscious that 'he who fights and runs away will live to fight another day.' In fact, after two weeks of hard fighting we were unable to discover one wounded warrior. . . . The single female (of *Phidippus morsitans*) that we caught during the summer was a savage monster. The two males that we provided for her had offered her only the merest civilities when she leaped upon them and killed them." "The female of *Dendryphantes elegans* is much larger than the male, and her loveliness is accompanied by an extreme irritability of temper, which the male seems to regard as a constant menace to his safety; but his eagerness being great, and his manners devoted and tender, he gradually overcomes her opposition. Her change of mood is only brought about after much patient courting on his part." In other species (*Philæus militaris*) the males take possession of young females and keep guard over them until they become mature. We sometimes hear of courtship by telephone. In the Epeiridæ spiders "it seems to be carried on, to some extent at least, by a vibration of web lines," as M'Cook and Termeyer have also observed.

Surely it is a long gamut this, from a mammal's clamant call and forcible wooing, or from the sweet persuasiveness of our singing birds, and the fluttering displays of others, to the trembling of a thread in the web of a spider. But, however varied be the pitch of the song and the form of the dance, all are expressions of love.

Mates are also attracted to one another by odours. These are best known in mammals (*e.g.* beaver and civet) and in reptiles; they predominate in the males, and at the breeding season. They usually proceed from skin glands; but we understand little about them. They serve as incense or as stimulant, but perhaps this usefulness is secondary. The zoologist Jaeger regards the odoriferous substances in plants and animals as characteristic of and essentially associated with each life; but without going so far we may recognise that in the general

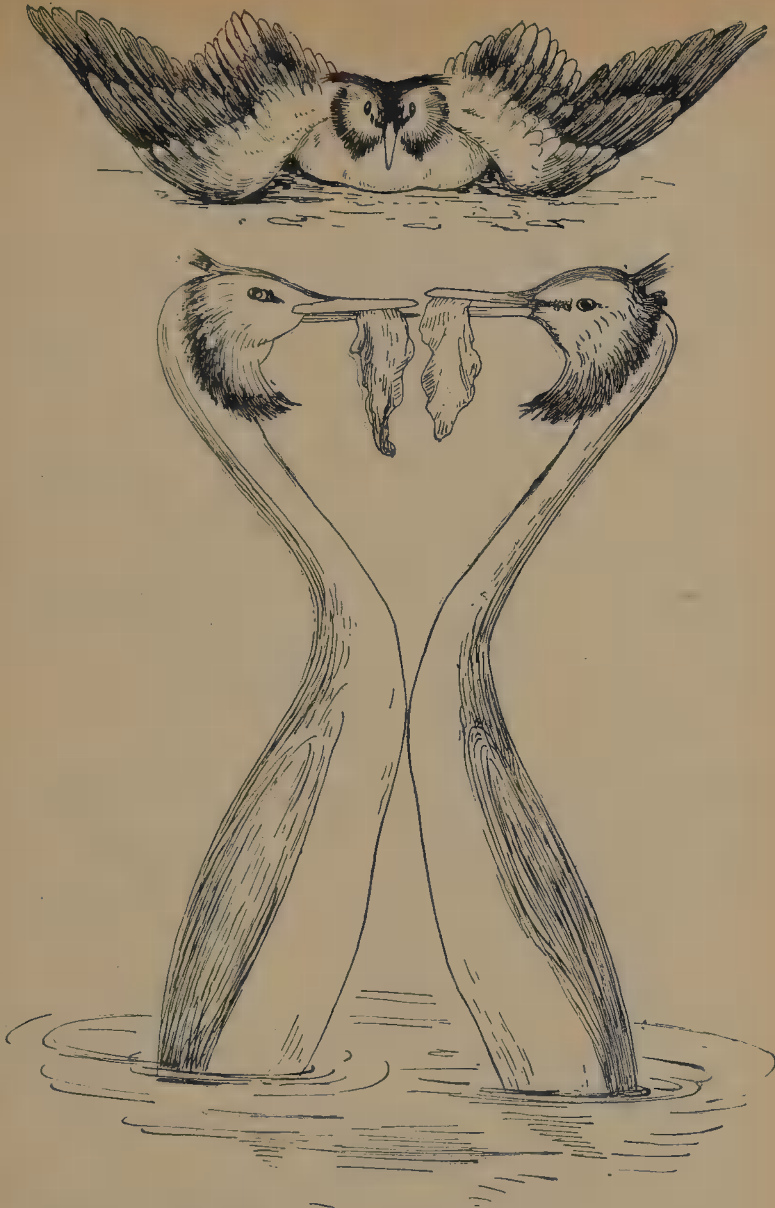


FIG. 32.—THE GREAT CRESTED GREBE.

The two figures here shown are copied from Mr. Julian S. Huxley's remarkable paper on the courting habits of the Great Crested Grebe (*Podiceps cristatus*), which will be found in the *Proceedings of the Zoological Society of London for* 1914. The elaborateness of ceremonial is very striking and instructive. The upper figure shows a female in the so-called "cat-attitude" of display ; it is also exhibited by the male. The lower figure shows the so-called "penguin dance" of the pair, in which they often hold weed in their mouths.

life of flowers and animals alike odours are very important. We know, too, that certain odours make much impression upon us; such as those of hawthorn and of the hay-field, of newly-mown grass and of withered leaves, of violet and of lavender; and furthermore, that in some mysterious way some fragrances excite or soothe the system, and have become associated with sexual and other emotions.

2. **Love and Care for Offspring.**—Gradual as the incoming of spring has been the blossoming of parental love among animals. We cannot tell in what forms it first appeared in distinctness. We cannot say Lo here! or Lo there! for it is latent in them all.

In many of the lower animals the units which begin new lives are readily separated from the parent; but in others, *e.g.* some of the simplest, or some by no means simple "worms," and even some insects, the parent life disappears in giving birth to the young. Reproduction or the continuance of the species often involves a sacrifice of the individual life.

It is strangely true, even in the highest forms, that reproduction, though a blossoming of the whole life, is also the beginning of death. It is costly, and brings death as well as life in its train. This is tragically illustrated by many insects, such as butterflies, who die soon after reproducing, though often not before they have, in obedience to instinctive impulse, cared most effectively for their eggs—the results of which they do not live to see. Think also of the mayflies, or Ephemeridæ, who, after a prolonged aquatic life as larvæ, become winged, dance in the sunlight for an hour, mate and reproduce, and die.

Picture the long larval life in the water, and the short aerial happiness lasting for an evening or two. Long life, compared with the span of many other insects, but short love; there may be years of patience, and but a day of pleasure; great preparations, and the anti-climax of death. The eggs develop in the water, and many of them are eaten by trout. In the survivors the embryos become integrated, awaken from their dreaming, and

turn themselves in their cradles. See the larvæ creep forth, wash themselves in the water, and hungrily fall upon their prey, some smaller insects. The wing-like tracheal gills grow out, and the air soaks into the blood; the larvæ cast their skins many times, and hide from the fishes. At length comes the final moult, and the unfolding of the gauze-like wings. In the summer evening you may see the first short flight as the insects rise like a living mist from the pool. But even yet a thin veil, too truly suggestive of a shroud, encumbers them; and they rest wearily on the grass or on the branches of the willow. Watch them writhe and jerk, as if impatient, till at length their last encumbrance—their "ghost," as naturalists call it—is thrown off. Now the other life, the life of love, begins. They dance up and down, dimpling the smooth water into smiling with a touch—chasing, embracing, separating. They never pause to eat—they could not if they tried; hunger is past, love is present, and in the near future is death. The evening shadows grow longer,—shadows of death to the Ephemeridæ. The trout jump at them, a few rain-drops thin the throng, the stream bears others away. The mothers lay their eggs in the water, and wearily die forthwith—cradle and tomb are side by side; the males also pass from the climax of loving to the other crisis of dying. But the eggs are in the water, and the dance of love is more than a dance of death. Turning homewards, we cannot but think sadly of other Ephemeridæ, of patient larval life, of the gradual revealing of the higher self, of shrouds thrown aside and wedding robes put on, of hunger eaten up by love, of the sacrifice of maternity, of cradle and tomb together. Yet we remember the eggs in the water, the promise of the future beneath the surface of the stream. Under the horse-chestnut tree, too, the wind has blown the shed petals like white foam, but the tree itself is strong like Ygdrasil, and among the branches a bird sings in the twilight.

Returning in more matter-of-fact mood to parental care, we need not dwell upon those cases where the young are simply sheltered for a while about the body of the

mother, hanging to a jellyfish, on some sea-urchins hidden in tents of spines, in various sea-cucumbers half buried in the skin, adhering to the naked ventral surface of the common brook-leech (*Clepsine*), imprisoned in modified tentacles in some marine worms, carried about in a dorsal brood-chamber in many water-fleas, or under the curved tail of higher crustaceans, retained within the gills of bivalves, and so on. Such adaptations are interesting, they involve prolonged physical contact between mother and offspring, but we are in search of cases where the parent acts as if she cared for her young.

But this care, as we said, begins very gradually. Thus, in some lowly crustaceans the young may return to the brood-chamber of the mother, even after hatching and moulting; and young crayfish are said to return to the shelter of the maternal tail after they have been set adrift. Strange, too, are the *males* of some sea-spiders (Pycnogonida), who carry about the ova on their legs. The freshwater mussel keeps the embryos imprisoned even after the normal period, until some freshwater fish be present, to which they may attach themselves; some cuttlefishes exert themselves in keeping their egg-clusters clean and safe.

But it is among insects, with their full, free life, that we see the best examples of parental care in backboneless animals. Some scoff at the "beetle-pricker" or the scarabeist,—and such genial laughter as that of the *Professor at the Breakfast Table* has a healthy resonance,—but those who scoff have not read Kirby's *Letters* or Fabre's *Souvenirs*, else they would know that the student of insects watches at a well-head of romance and marvel inexhaustibly fresh. What, for instance, shall we say of the worker-bees, who, though no parents, tend and nurse the grubs with constant care; or of the likewise sexless worker-ants, whose first endeavour when the nest is disturbed is to save, not themselves, but the young; or of the elaborate provisions that many of the digger-wasps and solitary bees make for offspring which they never survive to see? In regard to the puzzle presented by long-continued exertions towards an end

which is never experienced, it seems probable that there were ancestral forms, living in different climatic conditions, which did survive to see their offspring. A not uncommon kind of variation among animals is an alteration in the punctuation of the life-cycle—a lengthening-out of one chapter and a shortening of another. This may occur in adaptive relation to changed circumstances. It is also plain that types of mother-insect that made bad mistakes in regard to their offspring would be automatically eliminated, leaving the race more select. But after thinking out these explanations, the facts remain marvellous. Thus W. Marshall saw an ichneumon fly (*Polynema natans*) remain twelve hours under water, without special adaptations for such a life, swimming about with her wings, and depositing her eggs within the larvæ of dragon-flies !

We are accustomed, the same naturalist says, to look upon a hen which gathers her brood under her wings as a picture of loving care, but we must recognise that the same is true of earwigs, spiders, and scorpions. Some naturalists have described the pale-yellowish young earwigs crowding under the shelter of their mothers, who stand guard with open pincers, but there seems to be some doubt as to the accuracy of the observation. Female spiders, too, so fierce and impatient as mates, are most "respectable mothers." Some make nests, guard, feed, and even fight for the young ; others carry the eggs about with them. "I have often," Marshall says, "made fun of the little creatures, taking away their precious egg-sac and removing it to a slight distance. It was interesting to see how eagerly they sought, and how joyously, one may even say, they sprang upon their 'one and all' when they found it again. Sometimes I cheated them with a little ball of wool of the size, form, and colour of the egg-sac, which they quickly seized, and as rapidly rejected."

Many fishes lay their eggs by hundreds in the water, and thenceforth have nothing more to do with them, but even among these cold-blooded animals there are illustrations of parental care. From a bridge over the river

you may be able to watch the female salmon ploughing a furrow in the gravelly bed, and there laying her eggs, careful not to disturb the places where others have already spawned. In quiet by-pools you may find the gay male stickleback guarding the nest which he has made of twined fibres partly glued together with mucus. There the female has laid eggs, but he has driven her forth: he

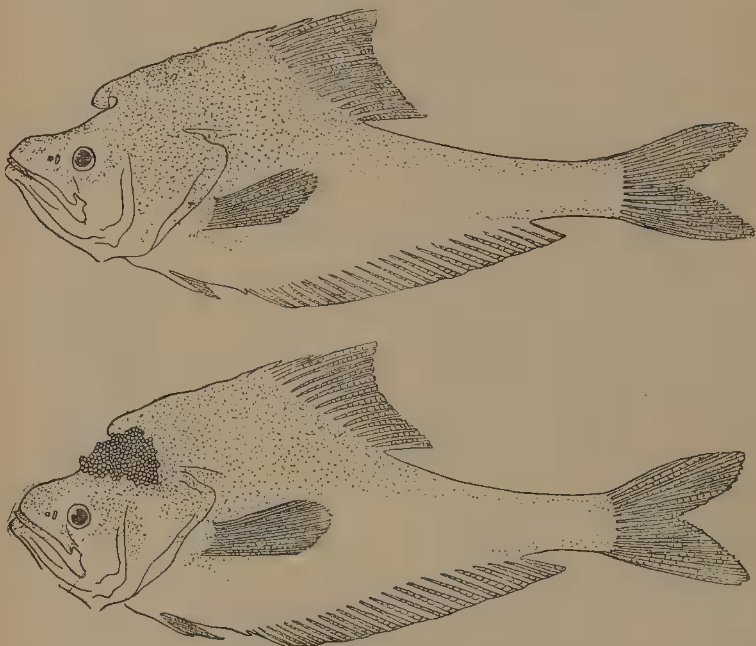


FIG. 33.—MALE OF *Kurtus gulliveri.*
(After Weber.)
The upper figure shows the bony hook on the top of the head. The lower figure shows the bunch of eggs in the hook.

will do all the nursing himself. No approaching enemy is too large for him to attack; his courage equals his seeming pride. When the young are hatched, but not yet able to fend for themselves, his cares are increased tenfold. It is hard to keep the youngsters in the cradle. "No sooner has he brought one bold truant back, than two others are out, and so it goes on the whole day long."

We do not know why the males among many fishes are so much more careful than the females. For the stickleback is not alone in his excellent behaviour. The male Chinese macropod (*Polyacanthus*) makes a frothy nest of air and mucus, in which he places his mate's eggs. He, too, watches jealously over the brood, and "has his hands—or rather his mouth—full to recover the hasty throng when they stray, and to pack them again into their cradle." Of all strange habits, perhaps that is strangest which some male fish (*e.g. Arius*) have of hatching the eggs in their mouths; what external dangers must have threatened them before this quaint brooding chamber was chosen! Or is it not almost like a joke to see the male sea-horse swelling up as the eggs which he has stowed away in an external pocket hatch and mature, "till one day we see emerging from the aperture a number of small, almost transparent creatures, something like marks of interrogation"? But some female fishes also carry their eggs about, attached to the ventral surface (in the Siluroid fish, *Aspredo*), or stowed away in a ventral pouch (in *Solenostoma*, allied to pipe-fishes), arrangements which recur among amphibians, but on the dorsal surface of the body.

FIG. 34.—SEA-HORSE (*Hippocampus guttulatus*). (From *Evolution of Sex*; after Atlas of Naples Station.)

A very remarkable adaptation securing the safety of the eggs has been described in *Kurtus gulliveri*, a small freshwater fish in New Guinea. The eggs are surrounded by coiled filaments closely wound, like the india-rubber thread in the core of a modern golf-ball. When they are laid the filaments uncoil automatically and the eggs are bound together in a double bunch, like a double bunch of onions. At the same time on the top of the male's skull a small bony process, like a bent finger,

grows forwards and downwards. Just before the hook-process becomes an "eye," the double bunch of eggs is in some way or other slipped in; as the "eye" is completed it is fixed; and the male goes about with the developing eggs on the top of his head. This case is peculiarly interesting because the two adaptations, which so perfectly fit, are, as it were, very far apart—the filaments round the eggs and the bony process on the male's head. Of this the female shows no trace.

Amphibians, like fishes, to which they are linked by many ties, are either quaint or careless parents. Again, the males assume the responsibilities of nurture. The obstetric frog (*Alytes obstetricans*), common in some parts of the Continent, takes the eggs from his mate, winds them round his hind-legs, and retires into a hole, whence, after a fortnight or so, he betakes himself to the water, there to be relieved by the speedy hatching of his precious burden. Even quainter is the habit of the male of a Chilian frog (*Rhinoderma darwini*), who keeps the eggs and the young in a ventral pouch (Fig. 35), turning a resonating sac in a most matter-of-fact way into a cradle. He is somewhat leaner after it is all over. It is interesting to notice how similar forms and habits recur among animals of different kinds, like the theme in some musical compositions. The spiral form of shell common in the simple chalk-forming Foraminifers recurs in the pearly nautilus; the eye of a fish is practically like that of many a cuttle, though the two are made in quite different ways; and an extraordinary development of paternal care may signalise animals so distinct as sea-spider, stickleback, and frog.

But we must not be unfair to the female amphibians. Without doubt most of them are willing to be quickly rid of their eggs or young, and as these are usually very numerous, the mortality in the pools is of little moment. In some cases, however, water-pools are less available than in Britain, and then we find adaptations securing the welfare of the young. The black salamander of the Alps, living at elevations where pools are rare, retains her twin offspring until more than half of the tadpole life

is past. They breathe and feed in a marvellous way within the body of the mother, and are born as lung-breathers. In the case of the Surinam Toad (*Pipa*), the male places half a hundred eggs on the back of the female, where they become surrounded by small pockets of skin, from which the young toads writhe out fully formed. In two other cases (*Nototrema* and *Notodelphys*), the above somewhat expensive adaptation, which involves a great destruction of skin, is replaced by a dorsal pouch in which the eggs hatch, an arrangement dimly suggestive of the pouch of kangaroos and other marsupial mammals.

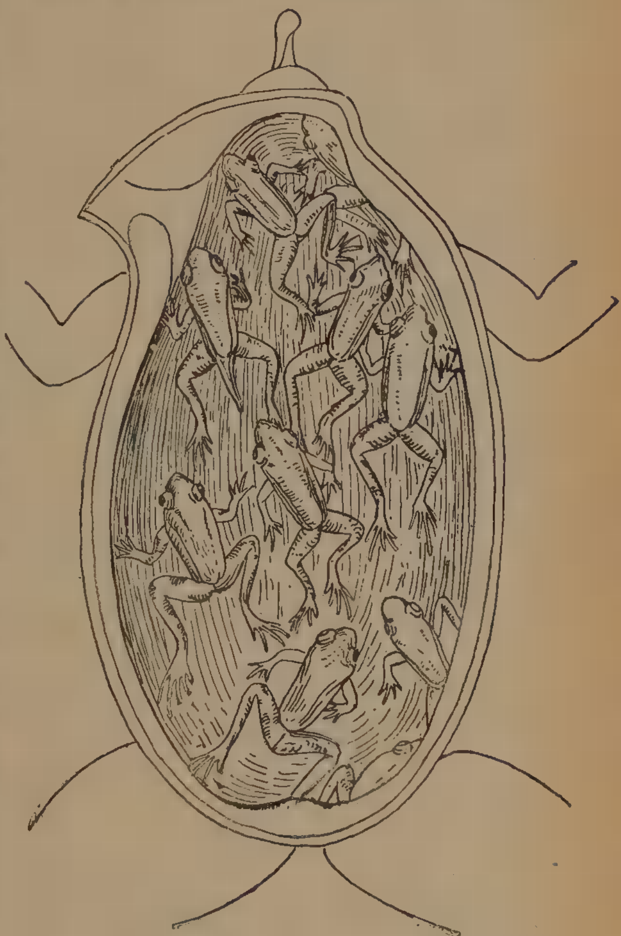


FIG. 35.—ENLARGED THROAT-POUCH OR CROAKING SAC OF MALE OF A SMALL CHILIAN FROG, *Rhinoderma darwini.* (After Howes.)

Within the pouch the eggs develop into minute frogs.

Fishes and amphibians are linked closely by their likeness in structure, and, as we have seen, they are somewhat alike in parental habits; but how great is the contrast between the habits of birds and reptiles, in spite

of their genuine blood-relationship. Yet the python coiled round her eggs is a prophecy of the brooding birds, as in past ages the flopping Saurians prophesied their swift-winged flight. The sharpness of the contrast is also lessened by the fact that a few birds, like the mound-builders, do not brood at all; while others, it must be confessed, are somewhat careless. But, exceptions and criminals apart, birds are so lavish in their love, so constant in their carefulness, that it is difficult to speak of them without exaggeration. Much of their carefulness seems to be instinctive and without thought (that is half the beauty of it); it is quite certain that many species would have gone to the wall long since in the struggle of life if the parents had not taken so much care of the young; but these considerations do not affect the *fact* that the creatures sacrifice themselves for the sake of their young to a most remarkable degree, and spend themselves not for individual ends, but for their offspring.

Before the time of egg-laying the birds build their nests, eagerly but without hurry, instinctively yet with some plasticity, and often with much beauty. On the laid eggs, which require warmth to develop, the mothers brood, and though to rest after reproduction is natural, the brooding is not without its literal patience. Among polygamous birds the males are, as one would expect, more or less careless of their mates, but most of the monogamous males are careful either in sharing the duty of brooding or in supplying the females with food. After the eggs hatch, the degree of care required varies according to the state of the young; for many are precociously energetic and able to look after themselves, while others still require prolonged nurture. They need large quantities of food, to supply which all the energies of both parents seem sometimes no more than adequate; they may still require to be brooded over, and certainly to be protected from rain and enemies. After they are reared, they have to be taught to fly, to catch food, to avoid danger, and a dozen other arts. With what apparent love—willing and joyous—is all this done for them!

Consider the cunning often displayed in leaving or approaching the nest, in removing débris which would betray the whereabouts of the young, or in distracting attention to a safe distance; remember, too, that some birds will shift either eggs or young to a new resting-place when extreme danger threatens; estimate the energy spent in feeding the brood, sometimes on a diet

FIG. 36.—NEST OF TAILOR-BIRD (*Orthotomus benettii*). (After Brehm.)

quite different from that of adult life; and acknowledge that the parental instinct is very deeply rooted, since birds (of both sexes) that have lost their young ones have been known to foster others. Listen to the bird which has been bereaved: is not the "lone singer wonderful, causing tears"?

The female of the Indian and African hornbill nests in a hole in a tree, the entrance to which she plasters up so that no room is left either for exit or entrance. The

Malays imagined that this was the work of the jealous male, but it is the female's own doing. "She sits," Marshall says, "securely hidden, safe from any carnivore or mischievous ape or snake stealthily climbing, while the male exerts himself lovingly to bring his mate those delightful things in which the tropical forest is rich—fruits above all, but occasionally a delicate mouse or juicy frog. He flies with his booty to the tree and gives a peculiar knock, which his mate knows as his signal, and thrusts her beak through the narrow window, welcoming her meal." At the end of the period of incubation, C. M. Woodford says, "the devoted husband is worn to a skeleton."

But animals, like men, have their vices, and birds, generally so ideal in their behaviour, are sometimes criminals. Ornithologists assure us that the degree of parental care varies not only in nearly related species, but also among members of the same species. We need not lay much stress on the fact that a bird occasionally slips its egg into a neighbour's nest, for when a partridge thus uses a pheasant's rough bed, or a gull that of an eider-duck, it is likely enough that the intruder had been disturbed from her own resting-place when about to lay. We approach something different in the case of the American Ostrich (*Rhea*), the female of which is quite ready to utilise a neighbour's burrow; nor does the owner seem to object, for all the brooding is discharged by the male, "and it is no great art to be patient and magnanimous at another's expense." Again, in the case of the American Ani (*Crotophaga ani*), of whose habits we unfortunately know little, a number of females sometimes lay their eggs in a common nest.

We are so glad to hear the cuckoo's call in spring that we almost forget the wickedness of the voluble bird. The poets have helped us, for they have generously idealised, in fact idolised, the cuckoo, the "darling of the spring," "a wandering voice babbling of sunshine and of flowers," a "sweet," nay more, a "blessed bird." But the cuckoos have hoaxed the poets, for they are even worse than their legendary reputation of being sparrow-

hawks in disguise; they are "greedy feeders," says Brehm, "discontented, ill-conditioned, passionate fellows; in short, decidedly unamiable birds." There is no true pairing; they are polyandrous. Perhaps the so-called "parasitic" trick is an outcrop of an egoistic constitution which shows its seamy side in other ways. The young bird, "a dog in the manger by birth," evicts the helpless rightful tenants whether they are still passive in the eggs or more assertive as nestlings, and grows up a spoilt child, giving his fascinated foster-parents no easy life.

We have spoken of the cuckoo as egoistic, and so on, but in the strict sense, of course, we are not justified in using words which suggest that animals are ethical agents. They exhibit self-regarding and other-regarding activities, but we have no reason to believe that they have any ethical or other concepts. They have the raw materials of morality, but they do not "think the ought." It is legitimate, however, if the evidence bears it out, to call a bird greedy, or passionate, or non-maternal.

A luminous suggestion in regard to the extraordinary case of the European Cuckoo has been made by Prof. F. H. Herrick, who points out that migrating, mating, nest-building, egg-laying, brooding, nursing, educating, and, again, migrating instincts in birds follow one another "with almost clock-like" precision in a definite harmonious series. In certain cuckoos and cow-birds the rhythm of the cycle has been disturbed. This has its counterpart in other cases where one link in the chain is drawn-out or another is abbreviated. Thus a bird may build two nests, or another may drop its egg on the ground, or another may migrate too soon. A lack of attunement between egg-laying and nest-making is a casual variation in many birds; it has become the rule in certain cuckoos and cow-birds, and the lack of attunement has been regularised and compensated for by "the parasitic habit."

There is much to be said about the domestic life of animals—their courtship, their helpful partnership, and

their parenthood—but perhaps we have said enough to serve as an introduction to a subject which will reward further study. Many of the deepest problems of biology—the origin and evolution of sex, the relation of reproduction to the individual and to the species—should be considered by those who feel themselves naturally inclined to such inquiries; moreover, in connection with our own lives, it is profitable to investigate among animals the different grades of the love of mates and of offspring, and to inquire into the great rôle that "love" in many forms has played in evolution. First, however, we should watch the ways of animals and seek after some sympathy with them, that we may respect their love, and salute them not with stone or bullet, but with gladdened eyes.

Ruskin's translation of what Socrates said in regard to the halcyon is suggestive of the mood in which we should consider these things.

Chærophon. "And is that indeed the halcyon's cry? I never heard it yet; and in truth it is very pitiful. How large is the bird, Socrates?"

Socrates. "Not great; but it has received great honour from the gods, because of its lovingness; for while it is making its nest, all the world has the happy days which we call halcyonidæ, excelling all others in their calmness, though in the midst of storm.

"We being altogether mortal and mean, and neither able to see clearly great things nor small, and for the most part being unable to help ourselves even in our own calamities, what can we have to say about the powers of the immortals, either over halcyons or nightingales? But the fame of fable, such as our fathers gave it to us, this to my children, O thou bird singing of sorrow, I will deliver concerning thy hymns; and I myself will sing often of this religious and human love of thine, and of the honour thou hast for it from the gods."

Chærophon. "It is rightly due indeed, O Socrates, for there is a twofold comfort in this, both for men and women, in their relations with each other."

Socrates. "Shall we not then salute the halcyon, and so go back to the city by the sands, for it is time?"

CHAPTER VII

THE INDUSTRIES OF ANIMALS

1. Hunting—2. Shepherding—3. Storing—4. Making of homes—5. Other instances of constructive skill—6. Movements.

Very early in the history of the human race there must have begun a differentiation of modes of livelihood. In certain places and among men of certain types, hunting and fishing became habitual arts. Elsewhere and among men of other mood pastoral life began, and the almost lost art of domestication had its early triumphs. Along a third line, but of course with interactions, agriculture developed, and with this we may reasonably associate the foundation of stable homesteads. And around the primary occupations of hunting and fishing, shepherding in the wide sense, and cultivating the soil arose more specialised activities, with division of labour between man and woman and between man and man.

Now, the activities of men suggest a convenient arrangement for those practised by animals. For here again there are hunters and fishers—beasts of prey of all kinds—pursuing the chase with diverse degrees of art; shepherds, too, for some ants use the aphides as cows; and farmers without doubt, if we use the word in a sense wide enough to include those who collect, modify, and store the various fruits of the earth.

In illustrating these industries, we shall follow a charming volume by Frédéric Houssay, *Les Industries des Animaux*, Paris, 1890 (trans. London).

1. **Hunting.**—Of this primary activity there are many kinds. The crocodile lies in wait by the water's edge, the python hangs like a liana from the tree, the octopus

lurks in a nook among the rocks, and the larval ant-lion (*Myrmeleon*) digs in the sand a pitfall for unwary insects. The angler-fish (*Lophius piscatorius*) is somewhat protectively coloured as he lies on the sand among the seaweeds; on his back three filaments dangle, and possibly suggest worms to curious little fishes, which, venturing near, are engulfed in the angler's wide gape, and firmly gripped by jaws with backward-bending teeth. Many animals prowl about in search of easy prey—eggs of birds, sleeping beasts, and small creatures like white ants; others would be burglars, like the Death's Head Moth (*Sphinx atropos*) who seeks to slink into the homes of the bees; others are full of wiles, witness the cunning fox and the wide-awake crow. Many, however, are hunters by open profession, notably the carnivorous birds and mammals.

Among these hunters there are many strange exploits; such, for instance, as that of a large spider which landed a small fish. The ins and outs of their ways are most interesting, especially to the student of comparative psychology. Think of the Indian *Toxotes*, a fish which squirts drops of water on insects and brings them down most effectively; several birds which let shells drop from a height, *e.g.* the Greek eagle (*Gypaëtos barbatus*), which killed Æschylus by letting a tortoise drop on his head, and the rooks which break freshwater mussels by letting them fall among the stones; the grey-shrike (*Lanius excubitor*), which spikes its victims on thorns; and, strangest perhaps, the slave-making expeditions of the Amazon ants. All strength and wiles notwithstanding, the chase is often by no means easy; the hare grows swift as well as the fox, many grow cautious like trout in a much-fished stream, scouts and sentinels are often utilised, the weak combine against the strong, and the victims of even the strong carnivores often show fight valiantly.

2. **Shepherding.**—Although the ants are the only animals which show a pastoral habit in any perfection, and that only in certain species (*e.g. Lasius niger* and *Lasius brunneus*), the fact is one about which we may

profitably exercise our minds. Let us follow Espinas's admirable discussion of the subject.

We may begin with the simple association of ant and aphides as commensals eating at the same bountiful table. But as ants discovered that the aphides were overflowing with sweetness, they formed the habit of licking them, the aphides submitting with passive enjoyment. Moreover, as the ants nesting near the foot of a tree covered with aphides would resent that others should invade their preserves, it is not surprising to find that they should continue their earthen tunnels up the stem and branches, and should eventually build an aerial stable for some of their cattle. Thither also they transport some of their own larvæ to be sunned, and as they carried these back again when the rain fell, they would surely not require the assistance of an abstract idea to prompt them to take some aphides also downstairs. Or perhaps it is enough to suppose that the aphides, by no means objecting to the ants' attentions, did not require any coaxing to descend the tunnels, and eventually to live in the cellars of the nests, where they feed comfortably on roots, and are sheltered from the bad weather of autumn. In autumn the aphides lay eggs in the cellars to which they have been brought by force or coaxing or otherwise, and these eggs the ants take care of, putting them in safe cradles, licking them as tenderly as they do those of their own kind. Thus the domestication of aphides by ants is completed.

3. **Storing.**—A beginning of storing may be looked for in activities like those of earthworms, which take leaves down into their burrows, at once making these more comfortable and providing a supply of food for the rainy day. Among insects we find a long inclined plane from the sacred scarabees, common in the Mediterranean region, which roll balls of dung to their holes, and gnaw at them at their leisure for days, to the hive-bees with their exaggerated storing instinct. The famous French entomologist Fabre (who died in 1915 at the age of ninety-two) has described inimitably how the mother scarabee moulds a pear-shaped mass of dung and deposits

at the narrow end an egg which occupies a special hatching chamber and has beside it a special first meal for the emerging grub! The Spanish Copris and some related dung-beetles are among the very few non-social insects with complete metamorphosis in which the mother survives to see the offspring attain the fully formed stage. The ordinary occurrence among the higher orders of insects is that the mother does not survive to see her young in the perfect state. In many cases she never sees her young at all, for she is dead before the eggs are hatched.

There is an evolutionist gratification in studying the storing activities of bees, for they are exhibited in such varied degrees of elaboration by different types. Among the solitary bees the mother makes a store for the brood which she very rarely survives to see; among humble-bees the store is begun by the mother but continued by her worker-children, and there are species (beyond British bounds) in which at least a part of the society survives the winter; in tropical species of the bees generically called Melipona and Trigona there are permanent societies but with imperfect combs; in the hive-bees we have to do with permanent societies and with perfect combs. The elaborate storing, carried to abnormal exuberance under man's domesticating tutelage, is correlated with surviving the winter, *i.e.* with permanence, and with the survival of the mothers after the adolescence of their offspring, *i.e.* with the possibility of social tradition.

As among bees, so among ants, we find all grades from those that do not store at all to those that make a fine art of it. According to recent studies of the common Mediterranean ant, *Aphænogaster barbarus*, the seeds which are collected are kept for a time dry and are eventually put out in the rain so that they begin to germinate. This has the advantage of bursting the hard seed-coats, and in some cases of starting processes of fermentation. At a certain stage, however, the ants kill the embryo-plant by biting off the radicle or other parts, and the seeds are dried again in the sun. According

to Neger the dried seeds, of some Leguminous plants for instance, are then taken back into the nest and chewed into dough. This is dried once again in the sun in the form of little biscuits, which are eventually put into the cupboard. It is probable that different kinds of seeds receive different treatment, and in some cases it seems that the stored material is not eaten after all, but is used as a culture for moulds (*e.g. Aspergillus niger*) of which the ants are very fond.

Among backboned animals it is difficult to find convincing instances of storing until we come to birds and mammals. Apart from the numerous birds that store food in their crops, sometimes so exuberantly that they cannot fly, there are some that may be said to lay up nutritive savings outside of themselves. The large Eagle Owl, which occasionally visits Britain, often gathers a huge superfluity of food (including hares and rabbits, poultry and pigeons) for his mate and offspring; and peasants have been known to utilise him as Elijah his ravens. There is an old tale that ptarmigan make stores of buds and berries beneath the snow, but there is no doubt that at least two species of woodpeckers store acorns, sticking them firmly into holes which are bored "for the purpose" in the tree stems. This is all the more interesting if it be true that what the woodpeckers really eat is not the acorn but a kind of grub that develops inside it.

Not a few mammals are in the habit of hiding away surplus food, and it is easy to imagine how this might lead on to a more definite storing instinct such as squirrels exhibit. In a number of different hoards the squirrel hides hazel-nuts, beech-nuts and acorns, and these may be a stand-by in the hard times of winter when the beautiful creature, who is not a true hibernator, is unable to sleep away its hunger, or when the young ones, who remain for a long time in the company of their parents, plead for food. In some mild parts of the country the squirrel's storing instinct seems to remain undeveloped. There are other mammals, such as the marmots, who make their burrows comfortable with

grass and shut the door when winter knocks; it is again easy to see that this might lead on to a definite hoarding of food supplies. Such hoarding is well illustrated by some of the light sleepers, such as dormice, who awaken from their hibernation whenever the weather is mild and are then inclined to have something to eat. In the burrow of the hamster several store-chambers are made, and grain, as well as hay, is accumulated in considerable quantity. We read that the people of Kamschatka rob the granaries made by one of the voles (*Microtus œconomicus*), and that the Mongolian herdsman brings his cow in autumn to eat the haystacks which are so diligently built in the summer months by the quaint tailless hares. We have not been able to verify in the field what has been circumstantially described, that moles make collections of decapitated earthworms—a store for days when the ground is gripped by unusually hard frost. We are told that these collected earthworms form a living larder, unable (as they could in summer) to regrow their lost heads, and therefore unable to crawl away. As moles are experts in dealing with earthworms and as decapitation interferes with co-ordinated movements, there is nothing incredible in the story. But it is a grim one!

4. **Making of Homes.**—Houssay arranges the dwellings of animals in three sets—(*a*) those which are hollowed out in the earth or in wood; (*b*) those which are constructed of light materials often woven together; and (*c*) those which are built of clay or similar material. We may compare these to the caves, wigwams, and buildings in which men find homes.

Burrows are simplest, but they may be complex in details. Those of the land-crabs (*Gecarcinus*), the wood-cutting bees (*Xylocopa*), the sand-martins, the marmots, the rabbit, the prairie dogs, illustrate this kind of dwelling in various degrees of perfection.

The male stickleback (*Gasterosteus*) weaves and glues the leaves and stems of water-plants; the harvest mouse (*Mus minutus*) twines the leaves of grasses or cereals together; the squirrel makes a rougher nest; but the

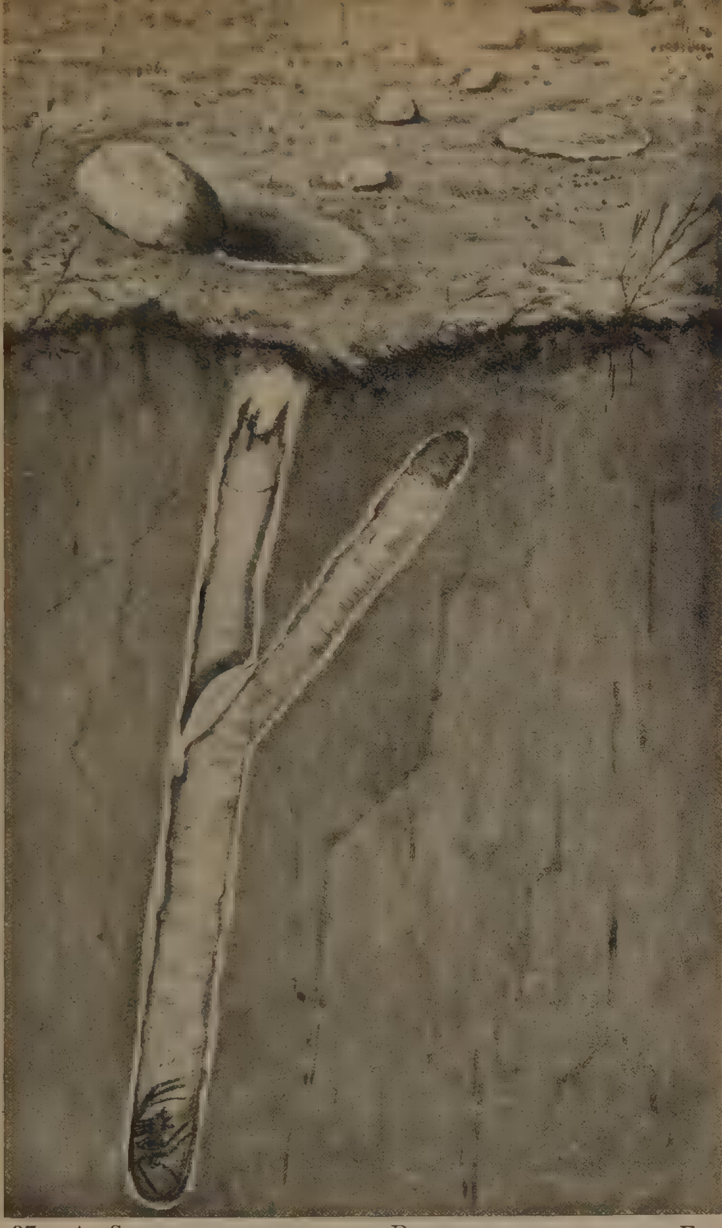


FIG. 37.—A SECTION SHOWING THE BURROW MADE BY THE FEMALE OF ONE OF THE TRAPDOOR SPIDERS.

(From a specimen and Moggridge.)

There is a neatly fashioned circular lid, externally like the surrounding earth. The figure shows an open and a closed lid. The lid is made of earth and works on a silken hinge; on its under surface there are some minute holes into which the spider fixes its claws in drawing the door shut.

The spider is seen at the foot of her nest or burrow.

There is often a side passage, as is shown. There is a hinged door which the spider can draw shut if it retreats into the side passage, *e.g.* before the advance of a digger wasp that has found the outer lid open.

nests of many birds are by far the most perfect works of animal art.

Of buildings, the martins' nests by the window, and the paper houses which wasps construct, are well known; but we should not forget the architecture of the mason-bees, the great towers of the termites, and the lodges of the beavers.

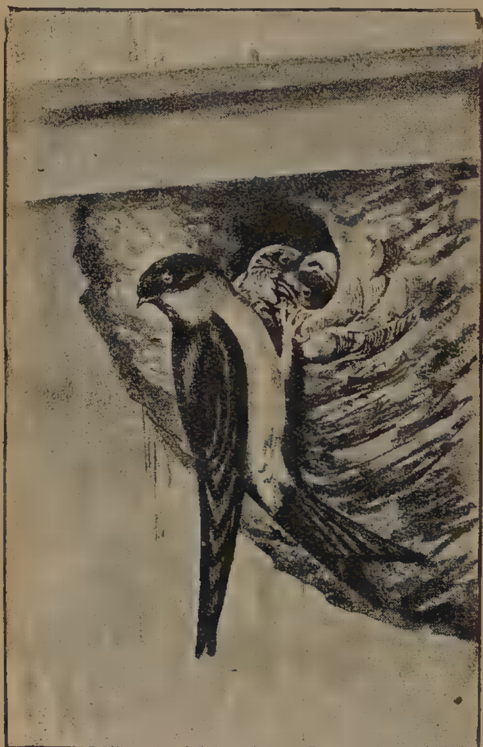


Fig. 38.—House-martin (*Chelidon urbica*) at its Nest. (After Brehm.)

It may be well to notice again explicitly, what has been suggested in another chapter, that while many of the shelters which animals make are for the young rather than for the adults, the line of definition is not strict, and some which were nests to begin with have expanded into homes—an instance of a kind of evolution which is recognisable in many other cases.

5. Other Instances of Constructive Skill.—As a familiar and at the same time supreme illustration of constructive skill, we may take the web-making of the garden-spider (*Epeira diademata*). (1) The spinner first forms the "foundation-lines" which enclose the area selected for the future construction. These are made particularly strong, for they may be used for more than one web. (2) From the upper foundation-line the spider drops to the lower, paying out a drag line as it sinks. This line

is pulled taut. Working from the centre to a foundation-line, always paying out a drag-line and pulling it taut, the spider forms "ray" after "ray," all intersecting at the centre. (3) Having made all the rays, the spinner starts from the centre, and taking big steps moves from ray to ray, leaving a strong spiral thread as it goes. This "primary spiral" is not viscid and serves simply as a scaffolding. (4) Finally, working from the outside inwards, and taking much shorter steps, the spider forms the permanent spiral, which is viscid and adhesive, and forms the chief part of the web. As the secondary spiral is completed, the primary spiral is eaten away. There is often a special thread running from the web to an ad-

Fig. 39.—Flight of Crested Heron, Ten Images per Second. (From Chambers's *Encyclop.*; after Marey.)

jacent hole where the spider lurks, for it is by vibrations rather than by vision that the advent of visitors is announced. It should be noted that the finer webs are made by the females, which seem to be all equally skilful—a feature characteristic of instinctive operations. Another important point is that the first true web a young garden spider makes is on the same general plan as the larger stronger ones afterwards formed. This again is characteristic of instinctive capacity.

6. **Movements.**—But animals are active in other ways. All their ways of moving should be considered—the marvellous flight of birds and insects, the power of swimming and diving, the strange motion of serpents, the leap, the

FIG. 40.—GOSSAMER.

Many small spiders often stand on tiptoe on the top of a fence or on a plant, secrete a parachute of silken threads, and allow themselves to be borne by the wind from one parish to another, or across a sheet of water, or even on to an island far from land. They can roll up their threads or lengthen them as they are borne along in their passive migration. The significance of the ballooning is probably to take the spiders away from a crowded area. It is commonest in autumn. When thousands of spiders do this and the broken-off threads sink on to the ground and hedges—often after serving their purpose—we speak of a shower of gossamer.

heavy tread, the swift gallop of Mammals. All their gambollings and playful frolics, their travels in search of food, and their wanderings over land and sea, should be reckoned up.

Most marvellous is the winged flight of birds. As a boat is borne along when the wind fills the sails, or when the oars strike the water, and as a swimmer beats the water with his hands, so the bird beating the air backwards with its wings is borne onward in swift flight. But the air is not so resistent as the water, and no bird can float in the air as a boat floats in the water. Thus the stroke has a downward as well as a backward direction. When there is more of the downward direction the bird rises, when there is more of the backward direction it speeds forward; but usually the stroke is both downwards and backwards, for the lightest bird has to keep itself from falling as it flies. The hollowness and sponginess of many of the bones combine strength of material with lightness, and the balloon-like air-sacs connected with the lungs help indirectly in the rapid breathing; but, buoyant as many birds are, all have to keep themselves up by an effort. But the possibility of flight also depends upon the fact that the raising of the wing in preparation for each stroke can be accomplished with very little effort; the whole wing and its individual feathers are adjusted to present a maximum surface during the down-stroke, a minimum surface during the elevation of the wing. There are many different kinds of flight, which require special explanation—the fluttering of humming-birds, the soaring of the lark, the masterful hovering of the kestrel, the sailing of the albatross. The effortless sailing motion of many birds is comparable to that of a kite, "the weight of the bird corresponding to the tail of the kite"; it is possible only when there is wind or when great velocity has been previously attained.

In connection with the movements of animals there arises the interesting problem of finding the way, which is illustrated by homing-pigeons, hive-bees, nesting-birds, and many other creatures. For hive-bees it has been

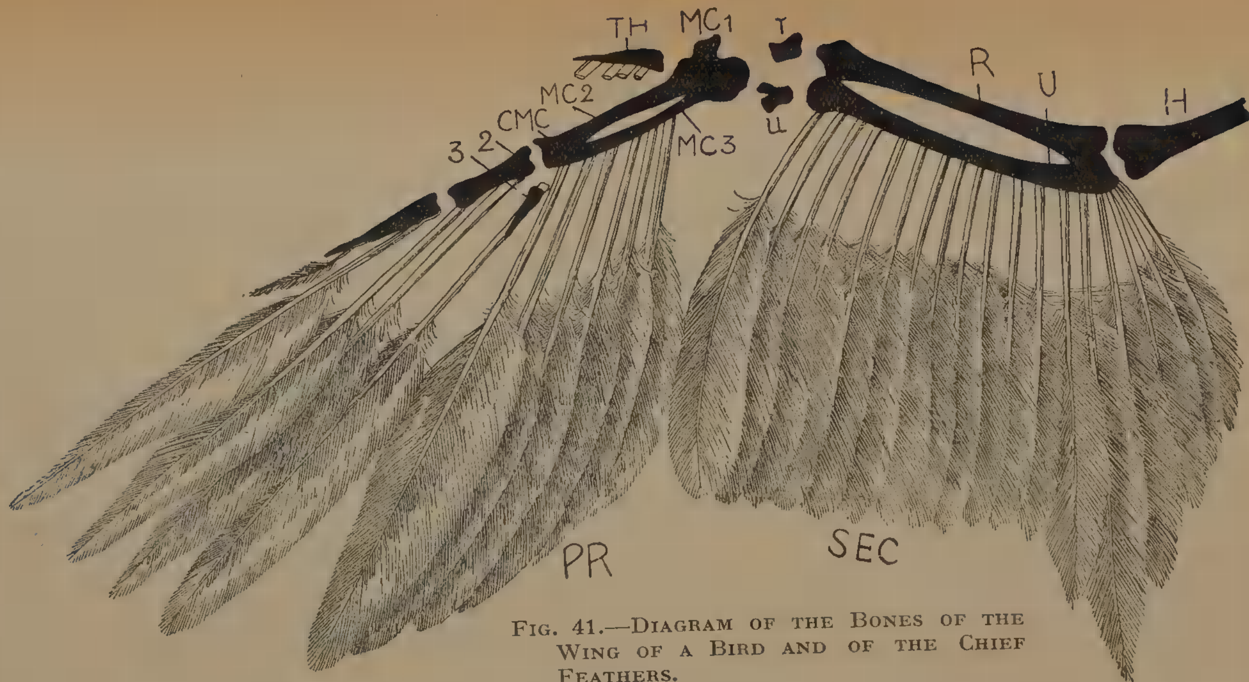


FIG. 41.—DIAGRAM OF THE BONES OF THE WING OF A BIRD AND OF THE CHIEF FEATHERS.

The student is strongly recommended to give reality to his reading by working patiently over such a readily available object as the wing of a bird—one of the finest illustrations of a well-adapted locomotor organ. *H* is the base of the upper arm or humerus. *R* is the radius in a line with the thumb (*TH*). *U* is the ulna, which should have been drawn rather thicker. At its upper end is the olecranon or elbow process. The ulna bears the second largest feathers, the secondaries (*SEC*); it is to the outer side of the fore-arm. The radius and the ulna are quite free from one another.

Of the original two rows of wrist bones only two are left, a radiale (*r*) and an ulnare (*u*). The distal carpals have fused with three metacarpals (*MC*1, *MC* 2, and *MC* 3) to form the carpo-metacarpus, a characteristic bird bone (*CMC*).

The single joint of the thumb carries a small tuft of feathers, the ala spuria. The longest feathers, the primaries (*PR*), are carried by the carpo-metacarpus and by digits 2 and 3. The second finger (2) has two joints or phalanges; the third (3) has but one.

proved that they build up a visual knowledge of the country around the hive. They are quite nonplussed when taken out a couple of miles on to a lake near the hive and liberated on the featureless water. In the case of ants the trend of investigation is against the hypothesis of any mysterious sense of direction. The little people seem to build up a working knowledge of their district, utilising various kinds of imprints or memories in finding their way home. Experiments show that they utilise hints derived from scents, the direction of the light, illumination of wayside objects, the turns and slopes of the road, and so on. Orientation is the outcome of a series of recognitions, differing for different kinds of animals; the recognitions depend on a previous registration of imprints; and the registration implies an hereditary sensitiveness exquisitely specialised.

CHAPTER VIII

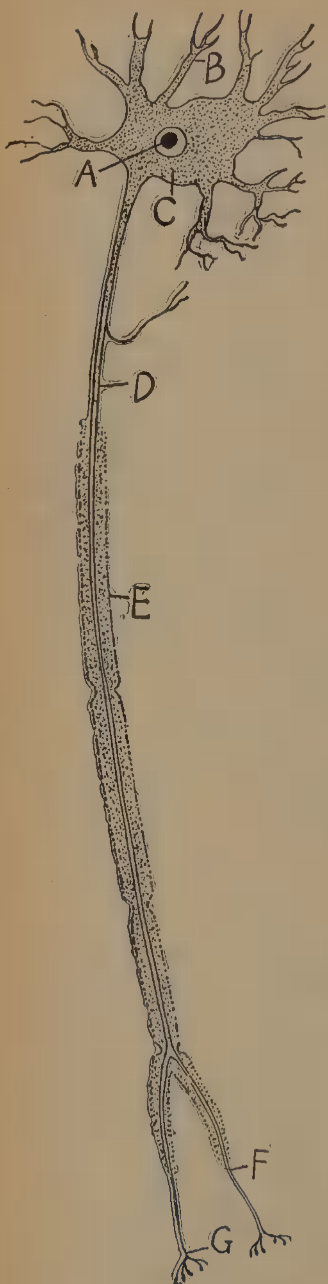
THE FUNCTIONS OF THE BODY

1. **Master Activities and Subsidiary Activities.**—Living means activity—activity swayed in great part by "hunger" and "love," if we use these words in their widest sense. Animals, as we have seen, busy themselves (in a delightful variety of ways) in finding food, making themselves comfortable, mastering their environment, avoiding their enemies, wooing mates, constructing nests and shelters, and tending the young. But all this depends on changes within the body—an animal is a dynamic system—for there is no movement without (1) the contracting of contractile substance (usually in muscle-fibres), and beyond the Unicellulars there is little behaviour that does not involve (2) the activity of nervous substance, which includes, along with "irritability," all the forms of mental activity. In short, there are *two master activities*, as Sir Michael Foster put it, in the animal body, contractility and irritability—those of muscular and those of nervous tissues. To these, the other everyday activities—of (3) nutrition, (4) respiration, and (5) excretion—are subsidiary or sustentative. As to nutrition, the energy expended in doing work has to be made good by taking in potential energy (like fuel) in the form of food, and this has to be made physically and chemically available (digested) before it can be in-

corporated in (or absorbed into) the living framework. As to respiration, vital activity implies many kinds of chemical change, but pre-eminently combustion or oxidation; and respiration is to be regarded as the taking in of oxygen to keep the fire of life burning, and the getting rid of the poisonous waste-product of combustion, carbon dioxide. The beginner who has got hold of the idea that respiration means "purifying the blood" should dismiss it, for it does not get at the gist of the business; and there are many animals without any blood. Moreover, plants have to "respire" as well as animals, though the respiratory function is disguised *during the day* in green plants by a counteractive nutritive process of utilising carbon dioxide in the photosynthesis of carbon compounds. As to excretion, the functions of the muscular and nervous tissues involve the production of nitrogenous waste-products, and there are other subtle waste-products that are formed in the various laboratories within the body; the filtering out or elimination of these nitrogenous waste-products (by the kidneys especially) is called excretion. The beginner should note that although the undigested and indigestible remains of the food are called excreta (*fæces*) when expelled from the food-canal, physiologists mean by the function of excretion the getting rid of nitrogenous waste-products.

We may say, then, that there are two *master activities* in the animal body—those of muscular and nervous tissues, and that there are three main *subsidiary activities*—nutrition, respiration, and excretion. The subsidiary functions are not ends in themselves as the master activities may be said to be, but they are the indispensable conditions of the muscular and nervous functions. It is useful to keep by themselves the *periodic functions* of growth and reproduction, though, as we shall afterwards see, they must not be separated off in any rigid way, since they are linked to the everyday processes of accumulating energy and repairing worn-out parts.

2. **Functions of the Nervous System.**—It is through the nervous system that the animal receives stimulation



from the outer world and controls its own activities. It is like a telegraphic system in a way, receiving messages from the outer world and sending out tidings to distant parts; it also integrates or co-ordinates the activities of all the organs of the body.

The unit in nervous reaction in any highly organised animal is called the reflex, and if we can in some measure understand it we have the key to the whole. Three structures are involved, a *receptor* (or end-organ), a *conductor*, and an *effector* (muscle). The receptor consists of sensory cells which receive stimuli from the outer world, and may be combined in a sense-organ. The conductor consists of nerve-cells or neurones which connect the receptor with the effector. Messages from the sense-cells travel along sensory or afferent nerve-fibres to the conductor cell or cells, whence excitation is conveyed to other motor or efferent neurones. From these a nervous impulse passes along motor nerve-fibres to the muscle, which

FIG. 42.—DIAGRAM OF A NERVE-CELL AND ITS FIBRES. (After Stöhr.)

A is the nucleus of the cell, *C* the central cytoplasm or cell-body. *B* is one of the dendrites, processes by which this nerve-cell communicates with adjacent nerve-cells. *D* is a nerve-fibre or neurite, enclosed in an envelope or sheath (*E*). It divides terminally into branches (*F*) going to muscles. *G* is a terminal organ on a muscle. Above *D* is given off what is called a collateral.

contracts. The whole nervous system is essentially a connected series of such reflex-arcs, all intricately joined up with one another.

3. **Muscular Activity.**—The common Amœbæ of the pond, irregularly shaped corpuscles of living matter, a hundredth of an inch or so in diameter, move about on a substratum in a remarkable and perplexing manner. Contracting a portion of their substance and pushing out a corresponding amount in another direction, they pull themselves, or glide, or roll along; but the procedure is not yet well understood. A similar kind of amœboid movement is common in certain cells of the body all through the animal kingdom. Threadworms and lancelets are among the few animals that have not wandering amœboid phagocytes. White blood-corpuscles or leucocytes are familiar illustrations of units that move in the amœboid fashion. It is said that cells at the attaching base of the freshwater Hydra may protrude amœboid processes, and thus move the whole polyp along the water-weed.

Another kind of locomotion is due to the action of cilia or flagella. Just as the amœboid mode is characteristic of the Rhizopod Protozoa, so the movement by cilia or flagella is characteristic of the Infusorians. Cilia are lashes of living matter which are alternately flexed and straightened, like our arm bent at the elbow and rapidly extended again; flagella move in an undulating fashion like snakes in the water. The Planarian worms, the Nemertean worms, the Rotifers or wheel-animalcules, may be mentioned as multicellular animals which depend, in part at least, in adult life on the activity of external cilia; and a very large number of free-swimming larvæ among Invertebrates (*e.g.* in Echinoderms, worms, molluscs) move by means of cilia. Even a newly hatched tadpole is covered with cilia. In threadworms and Arthropods cilia and flagella are practically absent, but in almost all other animals they are in evidence in various internal parts of the body, *e.g.* in the lining of our air-passages. In some cases, *e.g.* in certain starfishes, there are external cilia, no longer of use in locomotion, which

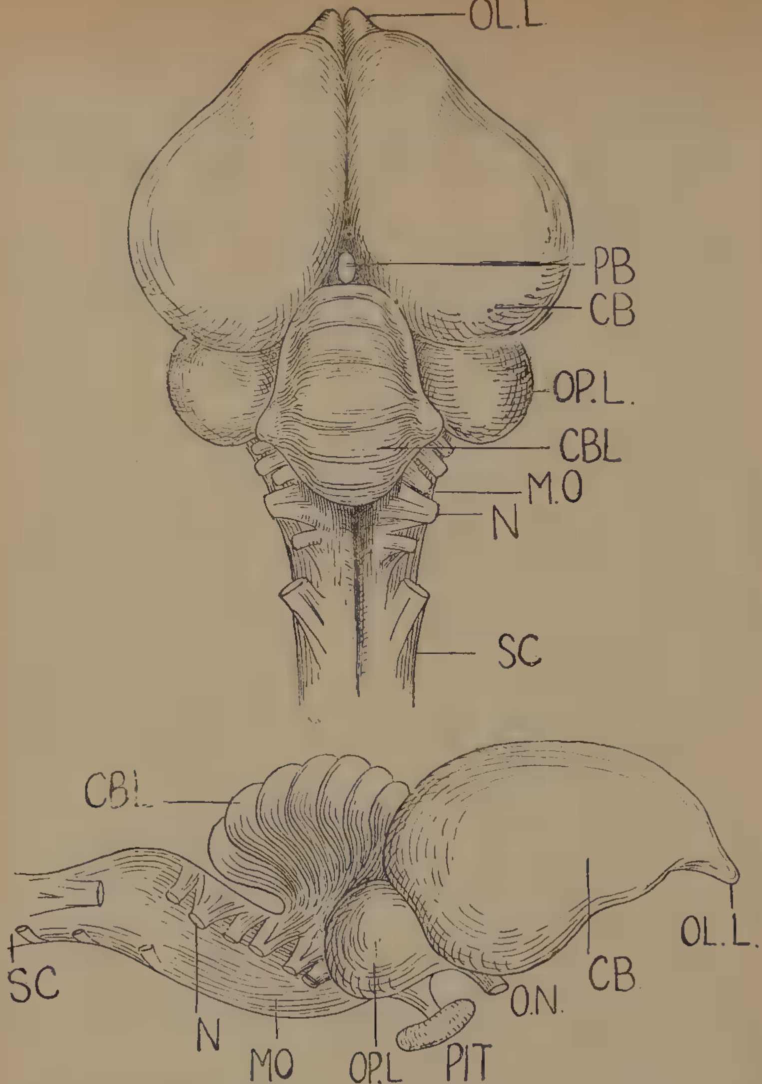


FIG. 43.—THE BRAIN OF A PIGEON, FROM ABOVE AND FROM THE SIDE.

OL.L, small olfactory lobes ; *CB*, large smooth cerebral hemispheres or fore-brain ; *P.B*, the pineal body rising from the roof of the second part of the brain, the optic thalami ; *OP.L*, optic lobes (the third part of the brain) which are thrust to the side in the course of development in birds by the preponderant growth of the cerebral hemispheres (*CB*) and the cerebellum (*CBL*) ; *PIT*, the pituitary body, a downgrowth from the region of the optic thalami which at an early stage in development meets an upgrowth from the roof of the mouth cavity and fuses with it ; it is in part an organ of internal secretion. The fourth part of the brain is the cerebellum (*CBL*) ; the fifth part is the medulla oblongata (*MO*), from which most of the cranial nerves (*N*) arise ; it is continued into the spinal cord (*S.C*). The optic nerves (*O.N*), seen far forward on the side view, arise from the optic thalami and have some of their fibres passing into the optic lobes.

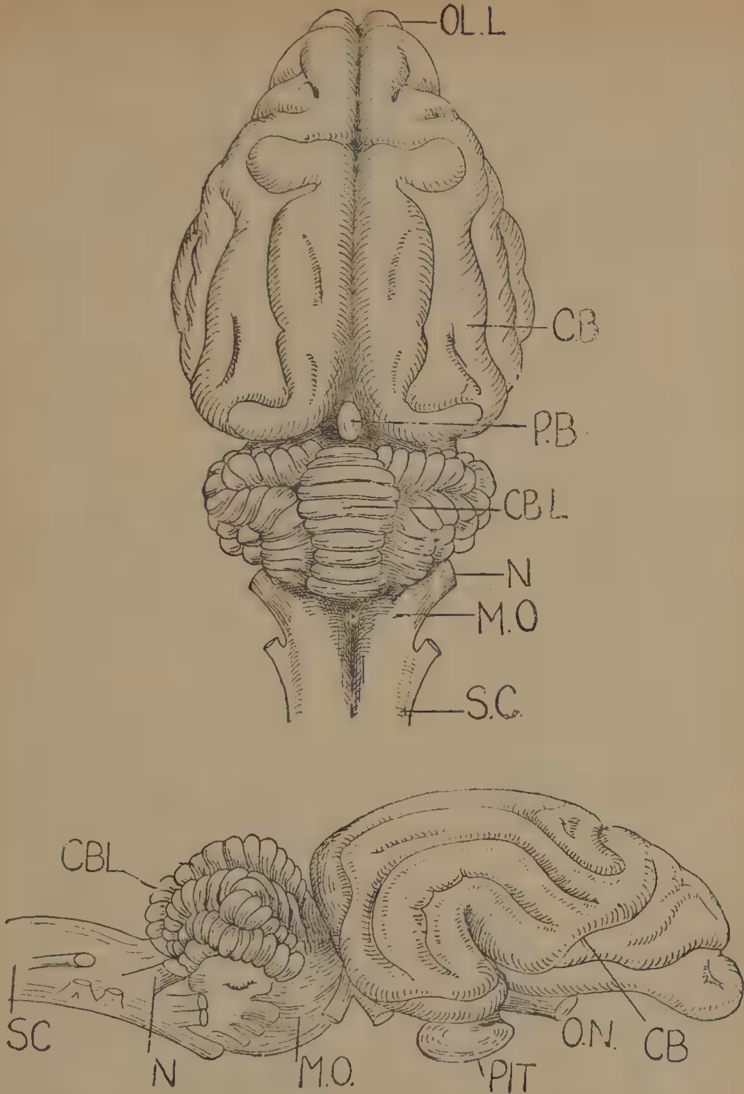


FIG. 44.—THE BRAIN OF A DOG, SEEN FROM ABOVE AND FROM THE SIDE.

OL.L, olfactory lobes well developed ; *CB*, the convoluted cerebrum ; *P.B*, the pineal body ; the optic lobes as well as the optic thalami are quite hidden ; *CBL*, the transversely grooved cerebellum, with a median lobe and two lateral lobes ; *O.N*, the origin of the optic nerves ; *PIT*, the pituitary body ; *M.O*, the medulla oblongata, from which numerous nerves (*N*) arise ; *SC*, the spinal cord.

play an important part in food-wafting, just as in the gills of bivalves which are really external organs.

Besides amœboid and ciliary movement, there is in rare cases among multicellular animals what may be called epithelial movement, where covering cells exhibit non-amœboid contractions and expansions.

In most cases, however, animals move by means of muscular tissue. Of this there are two kinds—unstriated and striated. Unstriated or "smooth" muscle consists of long flattened spindle-shaped cells with a central nucleus; these are bound together with a little intercellular cement into a band; and several bands may be bound together with connective tissue. Zoologically, it is interesting to notice that smooth muscle occurs in sluggish animals such as Ascidians and in the slowly moving parts of active mammals. In man and mammals it occurs notably in the walls of the food-canal, the bladder, and the blood-vessels (Fig. 45).

A piece of typical striated muscle consists of numerous fine fibres, each invested in a sheath (or sarcolemma), and all bound together by connective tissue. It usually runs from one part of the skeleton to another, drawing one piece nearer the other when it contracts. It is stimulated by motor nerves and is richly supplied with blood. In backboned animals the connective tissue envelope around a muscle is usually continued as a tendon on to a bone; in the extremely muscular Arthropods the tendons are strips of non-living chitin.

When a muscle contracts there is the obvious change of shape which we see and feel; it becomes shorter and broader. The energy expended in the work done is derived from an imperfectly understood chemical explosion in the muscle-fibres. Some explosive material is manufactured in the proteid framework of the muscle, the oxidation of sugar being probably involved in making the material. The muscle explosion produces heat, CO_2, and water. Lactic acid is also formed as a by-product in muscle-contraction; and with each contraction there is associated a change in electric potential. A similar electric change occurs when the leaf of Venus' Fly-trap

(*Dionæa*) closes on its victim. It should be noted that a muscle may contract in the absence of oxgyen or when only a little is available ; if this happens often there is an accumulation of lactic acid, and the proteid frame-work of the muscle goes out of gear, becoming coagulated, as also happens in the *rigor mortis* after death.

We cannot pass from the muscular system without recalling that it has an important function as a heat-producer. We are conscious of this "thermogenic" function when we take quick exercise, but heat is produced by muscle apart from contraction. The heat-production is perfected in birds and mammals—the warm-blooded animals (better called stenothermal or homoiothermal), where the temperature of the body is kept approximately constant, summer and winter, night and day. The regulation of production and loss of heat by means of the nervous system is brought about in an intricate automatic way, and it gives its possessors a great advantage over the cold-blooded (better poikilothermal) animals, such as reptiles, amphibians, and fishes, whose body-temperature always tends to approximate to that of the outside world. The heat-regulating or thermotaxis arrangements of birds and mammals are often imperfect in the young, and we know how quickly some nestlings will die if the mother-bird does not return. It is interesting to find that the three egg-laying mammals (Monotremes) are imperfectly

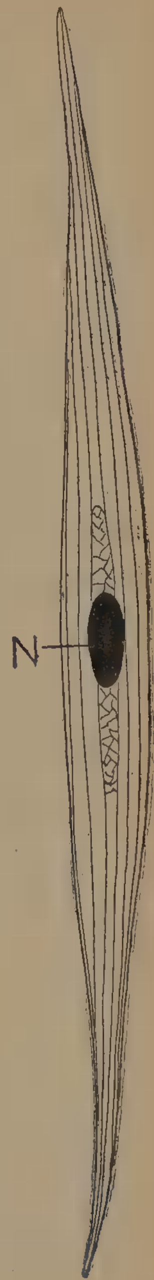


Fig. 45.—An Enormously Enlarged Diagram of a Smooth or Unstriped Muscle-cell. (After Schneider.)

It is spindle-shaped, and while there may be longitudinal lines there are no cross striations. Beside the nucleus (*N*), the fine reticular structure of the cytoplasm is shown.

warm-blooded, and the same is true of hibernating mammals. In the winter-sleep the attempt to keep up the warm-blooded regime is abandoned.

In the same connection it should be noted that there is an electrical change associated with every muscular contraction, and that this production of electricity (from modified muscle) becomes important in the Gymnotus, the torpedo, and other electric fishes. On another line, and very much more frequent, is the production of light, sometimes from within the substance of the cells of the luminescent organs and sometimes from a secretion exuded from these cells.

4. **Nutritive Functions.**—The energy expended in external and internal work is made good again by the raw materials taken into the body—proteids, carbohydrates, fats, water, and some salts. Whereas green plants can feed at a very low chemical level, getting carbon supplies from CO_2 and nitrogen supplies from nitrates and the like, animals must have carbohydrates, fats, and proteids already worked up by plants or by other animals.

The first step in nutrition is ingestion, which presents no problems of much theoretical difficulty. The Amœba engulfs its neighbour, the sponge wafts in minute organisms and particles, the starfish protrudes its stomach on its victim, the sea-cucumber thrusts its muddy tentacles into its mouth, the medicinal leech sucks in blood, the oyster wafts in diatoms and the like by means of cilia on its gills, the shark takes big bites, the frog shoots out its tongue on the insect, the python gets laboriously outside its big booty, the humming-bird sips nectar with its long tongue, the baleen whale catches myriads of minute molluscs in the sieve of whalebone which hangs down from the roof of its great buccal cavity. A radical distinction of importance is between the tough-mouthed animals that have something in the way of hard parts about the mouth and the tender-mouthed which feed mainly on small organisms and débris. Or we may classify animals as (1) carnivorous, (2) vegetarian, (3) those of mixed diet to whose mill many things

are grist, (4) those that depend on minute living organisms, and (5) those that feed on organic detritus.

The second step is digestion, dissolving the food and making it readily soluble. For the fuel of the living fire requires a good deal of treatment before it is really available. In some of the lower animals, such as sponges, the food-particles are engulfed by internal cells and digested within them. This is the Protozoon method and is called *intracellular* digestion. In most cases, however, the food is digested in the food-canal and then absorbed. This is called *extracellular* digestion. Both modes may occur together, as in Cœlentera and some simple worms. But above the level of worms the intracellular mode of digestion is dropped, and extracellular digestion occurs in the food-canal by the action of ferments or enzymes secreted by cells in the wall of the canal or in associated glands. Among these ferments may be noted the ptyalin of the salivary glands which changes starch into sugar, the pepsin of the stomach which turns proteids into peptones, the trypsin and other ferments of the pancreas. One of the peculiarities of these ferments is that a small quantity goes a long way and can act on a large mass of material without itself undergoing much change.

The third step is *absorption*, the digested food has to be carried to the various parts of the body and there incorporated into the tissues that need recuperation, or, it may be, stored for subsequent use. In backboned animals the digested carbohydrates and proteids are absorbed by mesenteric veins which combine into a portal vein that goes to the liver and breaks up there (the hepatic-portal system). The blood is re-collected from the liver after it has undergone some changes and passes by the hepatic veins to the heart, whence it is distributed throughout the body. The digested fat follows another course; it passes from the food-canal into a system of lymph-vessels, which communicate in various ways with the venous system and thus eventually with the heart.

5. Functions of the Liver.—The liver of higher animals

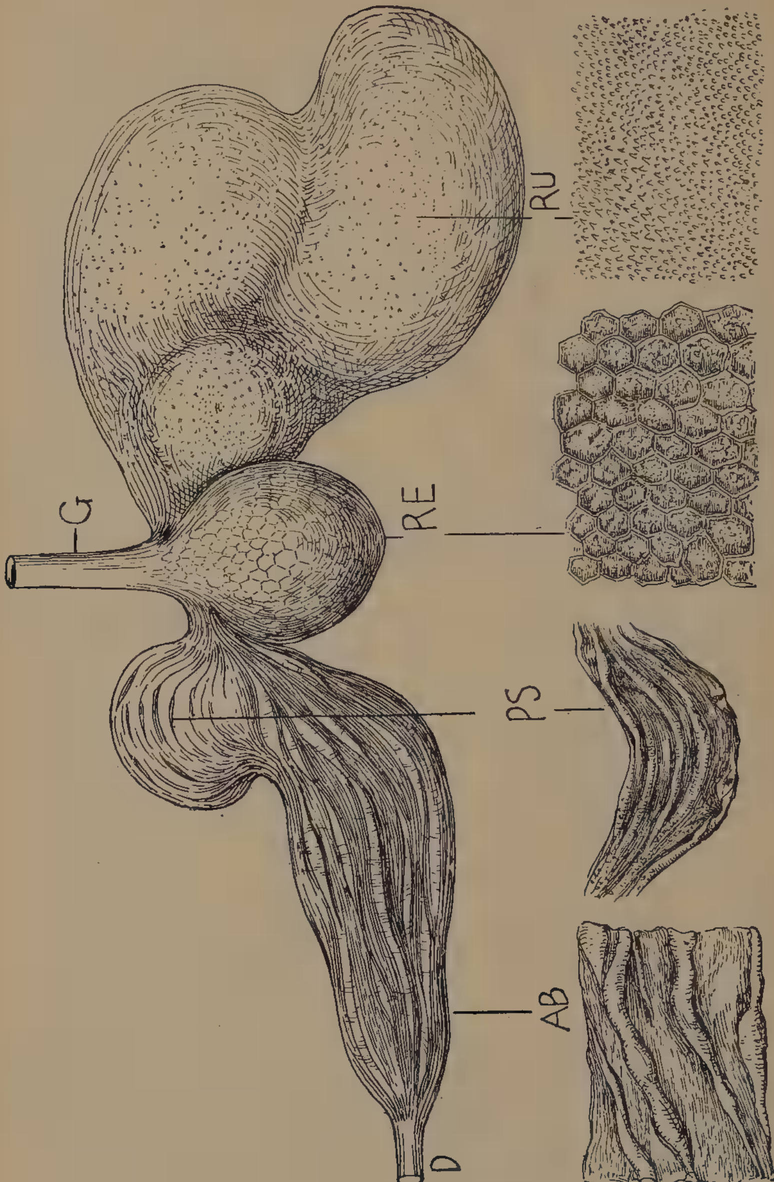

G
RU
RE
PS
AB
D

FIG. 46.—RUMINATION.

As a concrete illustration in connection with nutrition, we have figured the sheep's "stomach." If the whole structure is carefully cleaned, it can be cured and dried so as to form a permanent preparation. If a wooden mouthpiece is inserted at the gullet (*G*) and the beginning of the duodenum (*D*) is tied, the preparation can be inflated and made to appear somewhat as it is in life.

The grass hastily swallowed—for in wild life the herbivore is always in dread of the carnivore—passes into the first chamber, the large paunch or rumen [*RU*], which is covered internally with papillæ. A piece of the internal surface is shown. It is often compared to velvet pile.

An overflow from the paunch may pass into the second chamber, the honeycomb bag or reticulum (*RE*); it is usually the more fluid stuff which so passes. The internal surface has, as the name honeycomb suggests, a hexagonal pattern, part of which is shown.

Having filled its paunch and perhaps some of its honeycomb bag, the wild sheep seeks a place of safety where it may chew its cud without molestation, and domestic sheep sometimes show organic reminiscences of this ancestral habit. By a reversal of the swallowing movements it regurgitates the grass in boluses—a sort of normalised vomiting, but with a big difference to be noticed later.

In the mouth the food is thoroughly chewed and salivated and thereafter it passes down the gullet (*G*) for the second time. It skips the rumen (*RU*) and the reticulum (*RE*) and passes along a muscular groove, anterior to the latter, into the third chamber, the monyplies or psalterium (*PS*). In this it passes between a number of partitions or lamellæ, which serve as a sort of strainer or hopper. The salivary juice mixed with the food will continue its action on the starchy constituents.

Finally, the food reaches the fourth chamber, the reed or abomasum (*AB*), which has gastric glands on its walls. For it is the true stomach, and all the rest is a specialisation of the lower end of the œsophagus or gullet. The salivary digestive ferment (ptyalin) may operate in the first three chambers: gastric digestion (changing proteids into peptones by means of pepsin) is confined to the reed or abomasum.

is one of the largest organs in the body and one of the most important. It has many functions and may be described as a hard-worked organ, especially in man and domesticated animals where much energy is expended in dealing with the internal results of a life of ease. There is practically no disease of the liver or of any other organ in wild animals, except when some change of circumstances (oftenest due to man) exposes them to novel microbic or other parasites, to which they are unprepared to offer resistance.

All the products of digestion, except the fatty acids and glycerine which result from the action of pancreatic juice on fats, pass by the hepatic-portal system into the liver, which has to bear the brunt of everything before it is allowed to enter the general circulation. Thus many poisonous substances are arrested in the liver and prepared for elimination, and harmful substances are changed into harmless ones, and excesses of useful substances are kept back, and so on. The liver functions as a great selective sponge which keeps the composition of the blood approximately constant.

Starch in the food is digested into sugar, and this, along with the sugar in the food, is carried by the hepatic-portal system to the liver. During digestion there is an increase in the proportion of sugar in the portal vein going to the liver, yet there is no increase in the hepatic veins which leave the liver. This is an instance of the way in which the liver regulates the composition of the blood.

What becomes of the excess of sugar? It is stored in the liver, being synthetised into animal-starch or glycogen, which can be readily re-transformed into sugar, and passed on to the muscles to form explosives. Or it may be that the glycogen is stored also in the muscles. One of the great advances made by the French physiologist Claude Bernard was his discovery of the glycogenic function of the liver.

The liver has several other functions, such as the beginning of the preparation of nitrogenous waste-products for their final elimination by the kidneys.

Then there is the production of bile by the liver.

"It seems to have a slight solvent, emulsifying, and saponifying action on fats; in some animals it is said to have a slight power of converting starch into sugar; by its alkalinity it helps the action of the trypsin of the pancreas (which, unlike pepsin, acts in an alkaline fluid); it affects cell-membranes, so that they allow the passage of small drops of fat and oil; and it is said to have various other qualities." [1]

We have referred to this in a little detail because the contrast between the old pronouncement that the function of the liver is to secrete bile and what we know of its multiple vital functions is an index of physiological progress.

6. **Respiration.**—Life has been spoken of as a process of slow combustion, and it is certain that oxidations are continually occurring. To keep the fire of life burning, oxygen is needed, and that is the plus side of respiration. But the oxidations involve the formation of carbon dioxide, and the getting rid of this poisonous gas is the minus side of respiration. In general, the output of carbon dioxide is a measure of the rate of metabolism. In green plants in daylight there is a nutritive process of utilising the carbon dioxide of the atmosphere in the synthesis of sugar and the like, splitting it up, and returning the oxygen to the air; this disguises the respiratory process, which must be studied at night. There are some very puzzling cases among animals—*e.g.* parasitic threadworms living in a medium with no oxygen; it is probable that in these animals an oxygen-producing ferment or oxidase forms oxygen at the expense of some constituent of the body.

In Protozoa and simple aquatic animals the oxygen mixed in the water (familiarly seen as bubbles on the glass when a tumbler of cold water is brought into a warm room) diffuses into the living matter, which has a great affinity for it, and carbon dioxide diffuses out. As organisms became bigger and tougher, two improvements were effected, the blood, or it might be some

[1] The Author's *Outlines of Zoology*, 6th edition, 1914.

other circulating fluid, took on the function of distributing the oxygen to the tissues and collecting the carbonic acid; and special surfaces were developed where the blood was spread out and diffusion facilitated. These surfaces formed all sorts of gills in aquatic animals, and all sorts of lungs in terrestrial animals. The simplest of all arrangements we see in animals like the earthworm where the respiration is cutaneous, the blood circulating close to the surface all over the skin. To this primitive method there is often a relapse at much higher levels; thus the newly hatched tadpole and the adult frog lying passive in the mud in the winter-time are alike in showing cutaneous respiration. Of great importance is the presence of special respiratory pigments which have a strong affinity for oxygen and are therefore able to capture it readily, passing it on by and bye to the tissues. These pigments are usually in cells of the blood (as in red blood-corpuscles) or of the body-cavity fluid (as in sea-urchins), or in the fluid of the blood (as in earthworms); but they may occur in animals without blood or circulating fluid, as in sponges. Hæmoglobin, the red blood-pigment characteristic of Vertebrates, makes its first appearance in Nemertean worms; an analogous bluish pigment, called hæmocyanin, is common among Invertebrates. It is interesting to notice that the respiration of numerous simple animals, *e.g.* Stentor among Protozoa, Hydra among Zoophytes, and Convoluta among Planarians, is in great part secured by partner-Algæ with chlorophyll, which evolve oxygen in the sunlight and use the CO_2 produced by their partners.

7. **Excretion.**—Life is activity; this involves expenditure of energy; the supply of this is obtained from the reactions of chemical substances; and this implies the formation of waste-products. One of these is carbon-dioxide already referred to, but there are also nitrogenous waste-products which must be got rid of or converted into something not obnoxious. In plants they are deposited internally as crystals or in some other form; in some animals like Ascidians there seems to be a retention of nitrogenous waste in small reservoirs from which

there may be a slow diffusion outwards; in some other cases they may be in part utilised in forming skeleton; but in most animals their speedy removal is a condition of health. It is interesting to notice that in the winter-sleep of hibernating mammals like the hedgehog the ordinary excretory function of the kidneys is in abeyance.

Throughout the animal kingdom there is great variety in the method of eliminating nitrogenous waste-products. In the Protozoa there are often contractile vacuoles which accumulate fluid and burst to the exterior; in the Sponges and Cœlenterates the continual washing of the body—inside and out—with water secures the elimination of nitrogenous waste by diffusion. In most animals, however, there are kidneys of some sort, filters introduced into the blood-stream, which eliminate the poisonous waste. In the way in which they get rid of the injurious substances but do not let others, equally or more diffusible, pass out, they give us a glimpse of the intricacy of vital processes.

In mammals the kidneys filter out the nitrogenous waste-product called urea, and some other substances, chiefly salts. They also allow of the passage of a large quantity of water and a minute quantity of carbonic acid. They may be helped by the skin, which, in the perspiration, gets rid of much water, some carbonic acid, and some saline matter. But the chief use of the skin is to protect and envelop, and to help in the regulation of the body-temperature by alterations in the size of its blood-vessels.

8. **Organs of Internal Secretion.**—In Vertebrate animals there are a number of inconspicuous organs—glands of internal secretion—which are of fundamental importance. They produce substances which are carried away and distributed by the blood, and exert an indispensable regulatory influence on the activity of other parts of the body. Thus, in our own body, there is the small thyroid gland on each side of the windpipe below the larynx, which makes a secretion indispensable to the continued health of body and mind. Children in whom

the thyroid gland does not develop are cretins, dwarfed and unintelligent, but if they eat prepared thyroid of calf and the like or extract thereof they begin to develop both physically and mentally. They go on progressing so long as the artificial supply is kept up. Ingrafting a small portion of a normal thyroid has sometimes worked well. Disease of the thyroid results in the large neck-swellings known as goitre and in a serious disorder called myxœdema, both which are treated medically by thyroid diet and injections. An important colloid substance produced in the thyroid is called iodo-globulin, interesting chemically because of the presence of iodine. There are also minute quantities of arsenic in combination with nuclein-substances.

Some of the prescriptions of ancient physicians have often provoked a smile :—that the coward should devour the raw heart of the lion (if obtained by the patient himself cure was certain), that the weakly should eat the heart of an ox (as they often do), that the lethargic should dine on ram's brains, that the jaundiced should try the liver of a fox, and so on. Yet surely there is some approach to this in the modern thyroid treatment.

Another good illustration of organs of internal secretion is afforded by the two adrenal bodies which occur in the vicinity of the kidneys, on their upper edge in man. They are markedly divided into a cortical or peripheral and a medullary or central portion with different functions. When they are diseased in man there is deterioration of the skeletal muscles, a discoloration of the skin, and nervous disturbance. The central part produces a substance called adrenalin. If this is injected in very minute quantities into the circulation, it affects the sympathetic nervous system, and thereby quickens the heart-beat. There is a rise of blood-pressure which is due to a constriction of the muscular fibres of the minute blood-vessels or arterioles, and this has led to the use of adrenalin in surgery or in stopping a commonplace bleeding of the nose. The discovery of the rôle of internal secretions, for which Starling proposed the term "hormones," has had a very important influence on

physiology. Light has been thrown on the fact of physiological correlation, in which different parts work into one another's hands in a remarkably harmonious and adaptive manner, for the internal secretions are carried from organ to organ. Thus from the reproductive organs as they mature influences pass to distant parts of the body. In subtle ways the womb is prepared for the development of the offspring and the milk-glands for the day of its birth.

9. **Functions of the Blood.**—Many animals get on well without blood, but when these cases are examined it will be found that there are internal arrangements for keeping up currents of water or of nutritive fluid. A sponge often grows to be a large animal, but it is traversed by water-ways along which food-supplies and oxygen are swept in and waste-products swept out. Again, in an animal like the common jellyfish (*Aurelia aurita*), so often stranded on flat beaches, we can see that eight branched and eight unbranched canals radiate out from the central stomach and lead into a circumference canal round the margin of the disc. Thus the food in the alimentary system is carried everywhere. To take another example, the liver-fluke (*Distomum hepaticum*), which lives in the liver of the sheep (see p. 234), feeds on the blood of its host, but has no blood of its own. But it has a food-canal with extraordinarily complicated branching, which transports the nutriment everywhere, and still more branched is an excretory system which drains the leaf-like body of its nitrogenous waste. But while blood can be dispensed with, the advantages of its presence are obvious.

In a higher animal the chief functions of the blood are four. (1) It is a carrier of the digested food-stuffs. (2) In the arteries and pulmonary veins it is a carrier of oxygen (loosely united with the hæmoglobin of the red blood-corpuscles); in the veins and pulmonary arteries it is a carrier of carbon dioxide (loosely united with some constituents of the fluid or plasma). (3) It is a carrier of nitrogenous waste products. (4) It is a distributor of the hormones or internal secretions. In addition to

these functions, the blood is the main medium of the wandering amœboid cells or phagocytes which have many a rôle in the economy of the body, *e.g.* in dealing at strategic places with intruding microbes.

10. Modern Conception of Protoplasm.—Our knowledge of protoplasm—the chemical and physical basis of life—is still very incomplete. Perhaps our most certain knowledge of it is that in our brains its activity is associated with consciousness. Protoplasm appears to be a mixture of many substances among which various chemical reactions occur. Just as a firm may owe its success to the effective way in which the various members work into one another's hands, so part of the potency of protoplasm may be in the possibilities of interaction between the component substances. The most important of these substances are proteids or proteins, extremely complex compounds of carbon, hydrogen, oxygen, and nitrogen, with frequently a small quantity of sulphur. The characteristic percentage composition of proteids is indicated approximately by the numbers: carbon 53, oxygen 22, hydrogen 7, nitrogen 16, and sulphur 1–2.

The chemical changes that go on in the body are summed up in the word metabolism, and the most important of these may be ranked as either disruptive or constructive, katabolic or anabolic. There is a continuous twofold process of waste and repair, discharge and restitution, expenditure of energy and recuperation, running down and winding up. There is a synthesis of nutritive substances into complex molecules, such as those of proteids, and an analysis or explosion of these, with liberation of energy.

To this conception, however, there has to be added another, that each kind of living matter has an organisation, or in any case a substratum, of a colloid nature which is at once a product of the characteristic metabolism, and a physical system in which this continues to occur. Many of the characteristics of vital activities become more intelligible when the presence of the colloid substratum is recognised. Prof. Child has defined a living organism as "a specific complex of dynamic

changes occurring in a specific colloid substratum which is itself a product of such changes and which influences their course and character and is altered by them." Child writes :

> "The fundamental constituents of protoplasm occur in what is known as the colloid condition ; *i.e.* they do not form a true molecular solution, but exist as suspended particles larger than molecules in the fluid medium, which in the case of protoplasm is water. Living protoplasm may range in its physical condition from a semi-fluid to a stiff jelly-like substance according to the aggregate condition of its particles. This mixture of substances, protoplasm, is the visible substratum of the living form, and in it the changes which constitute life occur."

We believe that the reality of the organism is not exhausted by regarding it as a physico-chemical system, that it is also a psycho-physical system.

CHAPTER IX

ANIMAL BEHAVIOUR

1. **The Study of Behaviour.**—By behaviour is meant a correlated or concatenated series of activities in which the animal acts more or less as a whole, towards some definite result favourable to the continuance and harmony of its life or towards the welfare of the species. It depends on nervous and muscular functions, but it implies the co-ordination of these in effective agency. It means the accomplishing of the business of life, with its two chief ends, often interacting, of caring for self and caring for others.

There are many different *grades* and probably several different *lines* of behaviour ; thus it is probable that instinctive behaviour is on a different line from intelligent behaviour. The difficulty of right interpretation is great ; it is often especially hard to tell how much mental activity is involved. This difficulty is increased when the animals we are observing have a nervous system and sense-organs on a different plan from ours. Another difficulty is that all the available psychological terms are necessarily saturated with human meaning.

How are we to avoid the over-generosity of Montaigne on the one hand and the over-parsimony of Descartes on the other ? We do not wish to read the man into the beast without critical hesitation, neither do we wish

to give a false simplicity to the facts. The sound practical rule is to try to re-describe the observed behaviour in as simple terms as possible without leaving out any essential feature. The simplest description is not necessarily the true one, but we must hold to it till we are forced to give it up. Prof. Lloyd Morgan has clearly stated this canon:

> "In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale."

We propose in this chapter to illustrate what may be called the inclined plane or staircase of animal behaviour, but the student should bear in mind that there are more uncertainties than certainties. In the study of animal behaviour naturalists and psychologists are still feeling their way and most of the questions remain open.

2. **Restless Movements of Unicellular Animals.**—Many of the so-called simplest animals or Protozoa exhibit a restless movement which may be ranked at the foot of the inclined plane of behaviour, but not quite on it. So long as certain combustible or explosive substances within them last, and so long as certain outside provocations continue, the little creatures keep on moving, and we see them answering indifferently or distractedly to the various calls that summon them now to one side and now to the other. This locomotion is not much beyond the level of some of the ordinary functions which go on within higher animals, such as the beating of the heart or the movements of respiration. It may be called general organismal motor activity. There is a surplus of energy, and the simplest, crudest disposal of it is to keep moving on, but it should be noted that the restless roving contains the raw materials of hunting and exploration, and that the mode of locomotion is often very distinctive in detail. So soon is the note of individuality struck.

3. **Organic Reactions of Unicellular Animals.**—Many of the simplest animals respond by particular movements

to changes in temperature, illumination, chemical composition of the medium, and so on. As there is no nervous system, but simply a specific inborn protoplasmic organisation, which registers experiences, we may use the phrase "organic reaction" for this kind of answer-back to stimulus. It is in a far-off way comparable to a "reflex action" in a higher animal. Its rudimentariness is obvious in those cases where the same answer—the only one the creature has learnt—is given to every question or stimulation. To most stimuli the slipper-animalcule (Paramecium) responds by reversing its cilia, turning a

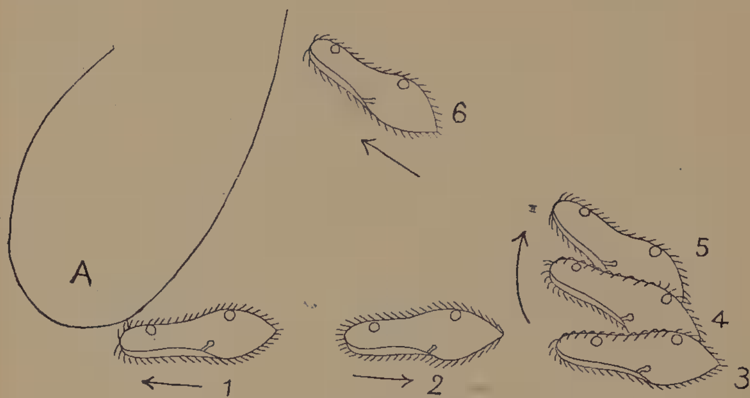


FIG. 47.—BEHAVIOUR OF PARAMECIUM.
(After Jennings.)

1. The Infusorian approaches an obnoxious influence, *A*.
2. It reverses its ciliary action and retreats.
3, 4, 5. It turns on its own axis.
6. It advances again, and if it re-encounter *A* it will repeat its reaction.
Paramecium swims habitually with a spiral movement of its body, for the aboral cilia strike more strongly than the others.

little on its axis, and then going ahead again in a slightly altered direction. This often enables it to evade an obnoxious influence and it is an illustration of the rudiments of behaviour. Prof. Jennings has shown that the Amœba in its mysterious gliding selects lines of flow which relieve it from hurtful stimulation.

4. **Trial and Error among Unicellular Animals.**—The observations of Jennings in particular have shown that many Protozoa exhibit what may be called a trial and

error behaviour. There is a trumpet-shaped ciliated Infusorian called Stentor which abounds in marshy pools, attaching itself by the narrow end to water-weed, and

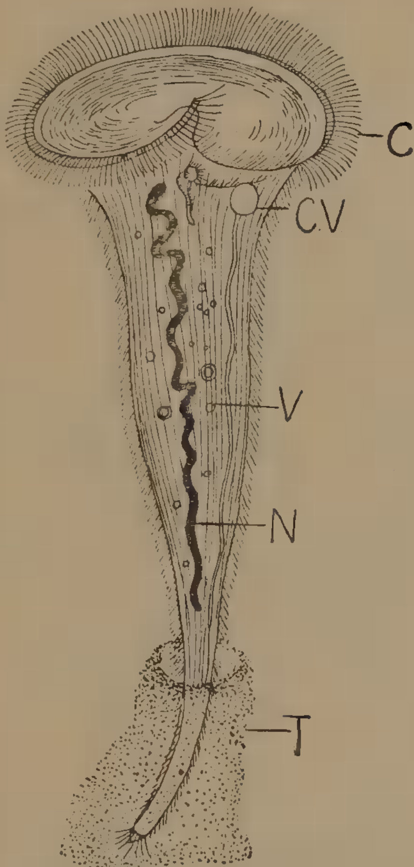


FIG. 48.—STENTOR.

In this Infusorian there are cilia over the whole surface and specially large cilia in a spiral wreath (*C*) around the mouth.

The lower part is surrounded by a mucus-like sheath or tube (*T*).

The macro-nucleus (*N*) is peculiar in being an elongated wavy band. There are numerous micro nuclei. Bubbles of water, "food-vacuoles" (*V*), surround the particles of food that have been taken in. A pulsating area or contractile vacuole (*CV*), with excretory significance, is also shown not far from the mouth.

There are longitudinal striations indicative of special threads (myonemes) of contractile protoplasm. Stentor is often bright green, which is due to the presence of numerous minute Algæ (Zoochlorellæ) living in symbiosis with it.

surrounding the lower half of its body with a mucus-like sheath, the so-called tube. If a cloud of carmine particles be introduced into the water-currents passing to the ciliated mouth of the Stentor, it bends to the aboral side, twisting on its stalk two or three times as it bends, and thus it often succeeds in avoiding the falling particles. This is answer one. But when the supply of carmine particles is kept up, the ciliary movement is suddenly reversed, and the water is driven away from the mouth. This is sometimes repeated two or three times, and is answer two. But if the Stentor does not get rid of the obnoxious stimulation in either of these two ways, it contracts into its tube and suspends activity. After half a minute or so it re-expands, and if the carmine particles still reach it, it contracts again. It will do this many times and after each contraction it stays a little longer in its tube than it did at first. This is answer three. Finally, if no improvement in circumstances rewards the Stentor's trials, it breaks from its attachment and swims forwards or backwards away from its tube. This is answer four. It will be seen that the animal tries a series of reactions until by one of them it gets rid of what was troubling it. "The phenomena," Jennings writes, "are thus similar to those shown in the 'learning' of higher organisms, save that the modifications depend upon less complex relations and last a shorter time."

5. **Reflex Actions.**—When we pass from unicellular to multicellular animals we find many illustrations of what are called reflex actions. They resemble the organic reactions already referred to, but are subtler and depend upon structural predispositions of differentiated nervous elements. The sea-anemone's tentacles close upon the piece of flesh when it touches them; the nestling's mouth opens at the touch of the food in its mother's beak; the earthworm withdraws into its burrow when it feels the tremor of a thrush's footstep; we cough in spite of ourselves when the crumb of bread is going the wrong way, and so on. In typical and simple cases, a reflex action involves (1) the "receptor"

of a stimulus—a sensory or perceptory nerve-cell from which impulses pass in to the central nervous system; (2) a "motor" nerve-cell which connects the central nervous system with a muscle, or, it may be, with a gland; and (3) between these two a "communicating" nerve-cell connecting them within the nervous system. But the pre-established arrangements are usually more complex, and several "reflex arcs" become interlinked.

Fig. 49.—Attitude of a Hen protecting her Brood against a Dog

(From Darwin's *Expression of Emotions.*)

The reflex way in which a crab throws off a limb that has been crushed or violently seized is nowadays simple physiologically as compared with the way in which the same is accomplished by a prawn.

Reflex actions are uniform reactions to a particular kind of external or internal stimulus; they are exhibited by all animals of the same species in approximately the same way, though some individuals are quicker than

others; they are independent of individual experience and do not require control on the part of the central nervous system; they depend on inborn structural linkages between particular sensory-cells which receive signal-messages, and particular motor-cells which issue commands to the muscles or to glandular organs.

There is no doubt that these reflex actions are sufficient to cope with many of the problems of life, especially among the lower animals. But there is much more. In difficult circumstances the creature tries a number of answers and persists along the line that pays, as we see when a starfish turned upside down tries to right itself. Or again, a customary reflex may be inhibited by what involves, or seems to involve, some appreciation of circumstances, as when a sea-anemone repeatedly cheated with false food ceases to exhibit the usual reflex response. The answer-back often varies with the physiological condition of the organism at the time, and this includes the registered results of past experiences.

6. **Tropisms.** — Another relatively simple kind of activity is seen in what are called "tropisms"—obligatory movements which tend to secure physiological equilibrium or comfort in reference to particular stimuli. When a moth, flying about, comes within the sphere of influence of a candle, and has one of its eyes much more illumined than the other owing to the way in which it happens to be flying, chemical processes are set up in the illumined eye which are different from (*e.g.* quicker than) those in the other. It follows that the nerves and muscles of the two sides of the animal are differently affected, and the moth tends to move so as to secure that the two eyes are similarly affected. Thus it may circle round and round the flame with a narrowing radius, and eventually into it. This, briefly stated, is an illustration of Loeb's theory of tropisms.

Tropistic movements are illustrated in reference to light, warmth, gravity, pressure and currents, odours and diffusing chemical substances, and they are of great importance in the lower reaches of life. Some believe that the "way-finding" or "homing" of migrating birds is

in part tropistic in relation to the magnetic currents of the earth.

A tropistic movement is the outcome of an attempt to secure physiological equilibrium, and it goes on till that is attained or till disaster ensues. They are obligatory in the sense that every creature of the same kind and in the same physiological state will in the same situation behave in the same way. But it is a notable fact that a tropism may be changed, reversed, or annulled by changes in the physiological condition of the body or by changes in the surrounding medium. There is experimental evidence that the tropistic movements may be occasionally interrupted by individual internal initiative on the part of the organism, may be inhibited or departed from under the influence of some stronger internal stimulus.

7. **Trial Movements.**—We have given prominence to reflex actions and tropisms because it seems certain that many of the movements of the lower animals are of one kind or the other. But it seems equally certain that there are a good many "trial movements" of a less obligatory character. As Jennings says: "Unprejudiced observation of most Invertebrates will show that they perform many movements which have no fixed relation to sources of external stimuli, but which do serve to test the surroundings and thus to guide the animal." Holmes writes:

> "The lives of most insects, crustaceans, worms, and hosts of lower Invertebrate forms, including even the Protozoa, show an amount of busy exploration that in many cases far exceeds that made by any higher animal. Throughout the animal kingdom there is obedience to the Pauline injunction, 'Prove all things, hold fast to that which is good.'"

Among simple multicellular animals there is not a little of that restless locomotion which we referred to as general organismal motor-activity in Infusorians. But at any moment this may give place to controlled behaviour. The creature makes sensori-motor experiments which work towards an end, such as the systematic

exploration of a corner in search of food. It shows control and selection. It may profit by experience, as may be seen in the way an inverted starfish is able to right itself more and more quickly day after day up to a certain limit—when it has done its best.

As the type-case of what we propose to call simply

FIG. 50.—YOUNG DUCKS CATCHING MOTHS.
(From St. John's *Wild Sports.*)

organismal behaviour (or sensori-motor behaviour) we take the attack which the brainless, ganglionless starfish makes on the brainless, ganglionless sea-urchin. The starfish lays an arm upon the spinose surface of the sea-urchin and grips with its suctorial tube-feet. The sea-urchin responds by biting with its numerous snapping

organs or pedicellariæ which close on the tube-feet. The starfish then draws away an arm, wrenching off the pedicellariæ. In the heart-urchin the pedicellariæ are separated off reflexly. The starfish repeats the process with the same or another arm until the sea-urchin is cleared of its weapons. The starfish then protrudes a portion of its very elastic stomach over its victim, and the business is over. Some items in the process are reflex, but the point is that the starfish exhibits a chain of actions, certainly not in the line of least resistance, which are mutually adjusted or correlated in such a way that they bring about an end—an end which is reached not immediately but eventually. In the absence of ganglia we may not speak of intelligent behaviour, but effective behaviour it certainly is. Many of the lower animals, then, show a trial and error method, a selection of the answers-back that put things right, and for a short time, at least, a capacity of profiting by experience.

8. **Instinctive Behaviour.**—Among the more complex animals there is abundant illustration of reflex and tropistic movements, but the greater part of behaviour is either instinctive or intelligent, or a blend of the two. Instinctive behaviour, such as is seen when a spider makes a web or the bees build a honeycomb, reaches its climax in insects. Intelligent behaviour, such as is illustrated when rooks break the shells of river-mussels by letting them fall from a height, or when collie-dogs learn to anticipate difficulties in bringing the sheep home, reaches a climax in higher Vertebrates, notably birds and mammals. Each of the modes has its particular excellences and limitations, and though they are, to our thinking, on different lines of evolution, they are often found in co-operation.

As a thoroughly typical instance of instinctive behaviour we take that of the Yucca Moth (*Pronuba yuccasella*) which has been often cited. When the large yellow bells of the yucca open, each for a single night, the silvery moth, just emerged from her chrysalis, sets forth to visit them. From the anthers of one she collects pollen, which she kneads into a ball and holds beneath

her head. She flies to another flower, pierces the pistil with her ovipositor, lays her eggs among the ovules, and then places the fertilising pollen-pellet in the funnel-shaped opening of the stigma. Without the pollen thus brought by the moth to the pistil the ovules would not develop. The larvæ of the moth eat a share of the developing ovules, but not more than about half are required. In referring to this extraordinary case, Prof. Lloyd Morgan writes:

"These marvellously adaptive instinctive activities of the Yucca Moth are performed but once in her life, and that without instruction, with no opportunities of learning by imitation, and, apparently, without prevision of what will be the outcome of her behaviour, for she has no experience of the subsequent fate of the eggs she lays, and cannot be credited with any knowledge of the effect of the pollen upon the ovules. The activities also illustrate what is by no means infrequent in the more complex instincts, namely, the serial nature of the adaptation. There is a sequence of activities, and the whole sequence is adaptive in its nature."

What are the general characteristics of instinctive behaviour as we see it in animals like ants, bees, and wasps, which belong to what Sir Ray Lankester has called the little-brain type, in contrast to animals like birds and mammals which belong to the big-brain type?

(1) Instinctive behaviour in its typical expression is specific or particulate. The garden-spider's web is not like the hedge-spider's web; the nest of one wild bee is not like another's; each species of wasp has its own way of dealing with its victims.

(2) The routine of instinctive behaviour is gone through with a considerable degree of perfection the very first time, and while it may be improved by practice, it certainly does not require learning or experimenting. It depends upon an hereditary predisposition of the nervous system. It "just comes" when the creature meets the appropriate stimulation.

(3) The capacity for a particular piece of instinctive behaviour is shared with approximate equality by all like members of the species. All the female spiders of a given species make an equally fine web; all the males an

equally inferior one. It must not be supposed, indeed, that instinctive capacities may not show variability; the point is that they are much more uniform than intellectual endowments. Perhaps one may venture to say that while intelligence is as much made as born, instinctive capacity is much more inborn than made.

(4) Instinctive behaviour is always adaptive in the normal conditions of the animal's life, though it may prove ineffective or misleading in face of peculiar exigencies. It has to do with particular external circumstances, particular stimuli and configurations, which frequently recur, or, if not, are of vital moment (as in the young bird's escape from the imprisoning egg-shell); and a slight change in the conditions is likely to result in extraordinary nonplussing.

The apartness of purely instinctive behaviour, as contrasted with that experimental, inferential, or reflective kind of behaviour which we call intelligent, is strongly suggested by its limitations. The French naturalist Fabre (whom Darwin called "that inimitable observer") relates that he induced numerous procession-caterpillars to move round the circular parapet of a fountain in his garden, and by adjusting the length of the procession got the head of the leader to touch the tail of the last member of the file. The living circle continued for days in futile circumambulation, obeying the instinctive follow-my-leader predisposition, which in natural conditions serves them well in their search for a suitable place in which to undergo their metamorphosis.

The grub of one of the mason-bees is hatched in a mortar-cradle, with a lid through which it has to cut its way. If the lid be artificially thickened by glueing on a piece of stout paper, this makes no difference to the success of the boring. But if a little empty paper-box be placed over the lid, the grub emerges into this, and having completed the boring part of its inborn routine cannot recommence it, and dies in its paper prison.

It is too soon to come to a conclusion in regard to the nature of instinct, for we have not the facts fully before us. (*a*) Some investigators regard instinctive behaviour

as closely comparable to a chain of reflex actions, depending on inborn structural predispositions of the nervous system, requiring no "mental" hand on the reins but merely the succession of stimuli. But many pieces of instinctive behaviour have a suggestion of being "suffused with awareness" and of having behind them a definite endeavour. (*b*) Others regard instinctive behaviour as quite inseparable from intelligence. But while it is admitted that a blending of the two is common, a study of both the achievements and the limitations of instincts does not seem to us to favour the view that instinct is a sort of low-grade intelligence. (*c*) According to others, instinct and intelligence are two radically different, though often co-operative, kinds of knowing, which have evolved along divergent lines.

It is probable that there are two distinct kinds of instinctive behaviour, that of ants, bees, wasps, and the like, on the one hand, that of birds and the like, on the other hand, for in the latter the inborn capacities are modified by experience from the earliest days onwards. There seems indeed to be a sharp contrast between (in Sir Ray Lankester's phrase) the big-brain type, which reaches its finest development in birds and mammals, and the little-brain type, the climax of which is in ants, bees, and wasps. The big-brain type is relatively poor in engrained capacities of instinctive behaviour, but is eminently educable. Thus the chick reared in the laboratory does not know what water is, even when it is standing in it and thirsty, it does not know what its unseen mother's cluck means, and it will stuff its crop once or twice with worms of red worsted. But it learns to find its way about with prodigious rapidity and profits readily by experience. The little-brain type, on the other hand, is rich in engrained capacities of instinctive behaviour, but is relatively non-educable. If a bell-jar be placed over the nest of a ground-wasp, from the door of which the inmates are wont to fly off, they are unable to force a way out through the grass pressed down by the edge of the glass. Yet the physical difficulty is not great, for those outside can force a way in. When they enter,

however, they cannot go out again, or give their fellow-prisoners a hint how to escape.

It must not be supposed, however, that animals of the little-brain type are unable to profit by experience. We know, in fact, that they build up complex chains of associations, as some ants do in learning to find their way home. Of twenty hive-bees which Prof. Yung of Geneva took into the country for a distance of six kilometres, seventeen returned to the hive. But when these seventeen were taken next day out on to the lake and liberated there, none returned. There seems little doubt that bees accumulate an acquaintance with certain features of the countryside around their hive.

9. **Intelligent Behaviour.**—Among birds and mammals in particular we find illustrations of a kind of behaviour which it is difficult or impossible to describe without using psychological terms. We see what looks like trial and error experiment, adapting means to ends, profiting by experience. We infer that it implies some "perceptual inference," some "putting two and two together," some working with ideas. It is reflective and experimental, as contrasted with instinctive and intuitive.

When the Greek eagle lets the tortoise fall from a height on the rocks below so that its strong carapace is broken, when beavers cut a canal right through an island in a big river—a task not practically justified till completed, when a collie dog at the bidding of a few sounds and signs accomplishes a really difficult thing in the way of sheep-driving, it is probable that we have to do with intelligent behaviour.

When Romanes's chimpanzee was asked for a number of straws up to five, it used to pick up the required number and present them with the ends exposed between finger and thumb. When it was right it got its reward. Sometimes, however, if asked for four straws, it would gather three to save time, and double one of them, so that four ends showed. When a reward was refused on such occasions, it would straighten out the doubled straw, pick up another one, and present the required

number. In a case of this sort we are inclined to admit intelligence, for the performance was rather subtle and novel, and we know that the chimpanzee has a highly developed brain.

Difficulties increase when we pass to animals very different from ourselves. Mlle. Drzewina removed some hermit-crabs from their borrowed shells and gave them similar shells which had been plastered up. The hermit-crabs spent a long time trying to get into these closed shelters, but eventually gave it up as hopeless. When some shells of the same sort, but empty, were put into the aquarium, the hermit-crabs would not look at them. The established association was too strong. Yet when some other shells of a different shape were put in, the hermit-crabs tried them at once. The question is whether we have here to do with intelligent behaviour, or whether it illustrates what we do not understand—a profiting by experience on a lower than an intellectual level, such as probably forms the basis of the very effective agency of the brainless starfish already referred to.

Strongly suggestive of something like intelligence is the behaviour of various kinds of animals, such as rats, dogs, cats, and chicks, which learn in the course of time to find their way out of labyrinths and puzzle-boxes. After they have served an apprenticeship they are left in peace for a few days and then replaced in the previous difficult situation. It is often observed that they make fewer useless movements, that they sometimes make none. The question is whether ideas are at work, whether the creatures think. Have they remembered images of their successful movements, or do they obey the promptings of an organismal registration in which ideas have not been involved? We must not be in a hurry in answering this question.

10. **Registration and Habituation.**—The problem of animal behaviour is complicated by the frequent occurrence of what may be called secondary simplicity. We are familiar with this in the individual "habituation" of exercises which originally required attentive selection and detailed control. This is more or less readily effected

in the individual by structural changes in the nervous system, but it is not known to what extent, *if indeed any*, the results of individual habituation can be entailed upon the offspring. The theory once widely held that instinctive predispositions to go through a certain routine are the hereditary results of lapsed intelligence is no longer in favour, mainly because of the difficulty of believing in the hereditary transmission of individually acquired characters. None the less, it may be said, it seems to be part of the strategy of Animate Nature to economise mental activity for higher issues by a structural organisation or registration (badly called mechanisation) of capacities for effective behaviour. It is probable that the steps in the hereditary organisation of behaviour are due to germinal variations ("inborn inspirations," some one has said) and not to the entailment of individual learning.

It is interesting to find that particular tropisms periodically repeated sometimes take such a grip of the individual constitution that they are exhibited even in the absence of the liberating external stimulus. Thus the little green worms called Convolutas, well known on some flat beaches, as at Roscoff in Brittany, come up out of the sand when the tide goes down, and retire into the sand when the tide comes up; and Bohn has demonstrated that they will go on doing this for a couple of weeks in a tideless aquarium away from the sea, or even in a test-tube with some sand. Similarly, some hermit-crabs which are in the way of making for the light at high tide and away from the light at low tide, will continue to do this for some days in a tideless aquarium. Periodic activities often repeated seem to take a grip of the body, becoming in some way enregistered.

11. **Rational Conduct.**—In the case of man, and probably in his case alone, there is sometimes evidence of rational conduct as contrasted with intelligent behaviour. We cannot describe such conduct without using general terms; it involves experimenting with ideas, conceptual as distinguished from perceptual inference; it is controlled in reference to an ideal or a

conceived purpose. Much of man's activity is intelligent behaviour, much is intelligent behaviour that has become habitual, but in either case there may be, if occasion arise, an instantaneous transition to the higher level of rational conduct.

12. **Artistic Skill.**—Most of the Foraminifera form shells of lime, which are often of great beauty. There are others which make shells of extrinsic particles selected from the surroundings and effectively built together. We are here contemplating the dawn of art. In their interesting studies on arenaceous Foraminifera Messrs. E. Heron-Allen and A. Earland have disclosed a remarkable series of facts. One species of Foraminifer (though it is difficult to say what species means here) will use nothing for its encasement save intact sponge-spicules, a second will use only grains of quartz, and a third flakes of mica. Quite extraordinary is a species of Technitella (*i.e.* "little workman") which makes its test of delicate Echinoderm plates, and, having no definite oral aperture, sends its threads of protoplasm through the pores which the plates possess. Very striking also is a species of Reophax which forms a fragile many-chambered tube, built of infinitesimally small flakes of mica, joined at their extreme margins by chitinous material. When the Protozoon is living, this delicate covering is pliable like chain armour. The striking facts are individuality of architecture and the apparent selection of particular kinds of material from amid an embarrassing multitude of alternatives. Experiment is needed to show how far this is obligatory, how far facultative.

Very interesting, furthermore, is the effective way in which some of these shell-builders use their materials. In a species of Technitella the whole shell-wall consists of two distinct layers of sponge-spicules, "giving as close an approximation to the woof and warp of a textile fabric as is possible with a rigid non-flexible material such as sponge-spicules." In some forms the sponge-spicules are arranged protectively, in others there are long projecting rods, like "catamaran spars," which support the shell on the surface of the ooze. Two or

three individuals may be united in this way by sharing spars, "the association offering greater resistance to the mud than a single individual can attain." Gaps in the wall of the shell of a species of Psammosphæra are filled in with fragments of spicules "carefully selected for length so as exactly to fill the spaces that are to form the walls of the test, an awkward triangular space being frequently filled in with a truncated triaxial spicule." Very instructive is the story of *Marsipella spiralis* which arranges its borrowed sponge-spicules in a left-handed spiral and embeds them firmly in cement, thus improving on the shell of its neighbour-species *M. cylindrica*, which forms a long and exceedingly friable tube. Mr. Heron-Allen compares *M. spiralis* to the prehistoric genius who invented string—"it has clearly realised that a twisted yarn is stronger than an untwisted wisp of fibre." This phraseology is too anthropomorphic, but it probably expresses a great truth, that all through the animal kingdom there is organic skill, associated with different degrees of awareness. One of the ways in which those psycho-physical individualities which we call organisms express themselves is in the skilful use of materials.

Among tube-building worms, tailor-crabs, hive-bees, wasps, spiders, and so on up to nest-building birds, we see individual, specific, effective, adaptive, and beautiful utilisation of materials, and often a remarkable triumph over the difficulties which they involve. Just as we may distinguish rational skill, intelligent skill, and instinctive skill, so there may be, in the arenaceous Foraminifera referred to, an organic skill, when the simple individuality, pulling itself together, acts as a unity and then perhaps feels itself as one. For it is not fantastic to suppose that in such critical moments of endeavour and adventure consciousness first found, and still finds, its simplest glimmering expression. Perhaps we are nearer the truth in supposing that Technitella says to itself in some quiet way of its own "Anch' io sono pittore," than in supposing that its remarkable artifice can be exhaustively described in terms of surface-tension.

13. **Spontaneity.**—We cannot evade the difficult ques-

tion whether the behaviour of organisms has any real spontaneity, precluding or limiting the possibility of prediction, or whether the suggestion of spontaneity is fictitious, and due to the complexity of the conditions. It was once true to say that the wind bloweth where it listeth, but now the meteorologist tells us whence it cometh and whither it goeth. Are we, in our ignorance or obscurantism, postulating for the living creature a spontaneity and unpredictability such as our forefathers believed to be exhibited by the wind? This is a very difficult problem—the problem of *biological determinism*, analogous to the problem of *psychological determinism* and free will. We venture to say just a little on this difficult problem.

As we ascend the scale of being there is a growing amount of what may be called "experimental indeterminism." It is plain, for instance, that an organism is free as compared with a not-living system. The living creature has alternatives, the inanimate system none.

When we begin experimenting with a starfish, we cannot tell what it will do in the various circumstances in which we place it. But after we have experimented for a long time we can tell what the starfish, whose intimate acquaintance we have made, will do under certain circumstances, provided always that we know its "physiological condition at the time." The behaviour of a hermit-crab and even its reflexes may be profoundly altered if it be taken out of its borrowed shell. And just as "a hungry man is an angry man," as every household knows, so a hungry starfish does not behave as a full-fed one does. Now, if we are rash enough to make a prediction in regard to the behaviour of a fresh starfish of the same kind and weight and size, we are very likely to be very far wrong. Why is this? It is otherwise in the inorganic world, where we can safely argue from one thing to another thing of the same kind.

The difference is not one of complexity, but of kind. The starfish is not mechanically necessitated to act as it does; it checkmates mechanism because it is organism; it is ruled by its own brainless, ganglionless constitution

which it as a psycho-physical individuality has itself been an agent in building up.

Similarly, our argument runs, an animal with a big brain, *i.e.* a well-developed capacity for experimental behaviour, is free as compared with a starfish. By careful study we can reduce the experimental indeterminism, which increased as evolution advanced, and we can predict with some success what *our dog* will do in a particular situation. But we are likely to make a bigger mistake than we made with our starfishes if we argue from our dog to our neighbour's. And why ?

The individuality of the dog is so much greater than that of the starfish. It is ruled less by its general constitution and much more by its cerebral constitution (psycho-physical) which it has itself been an agent in building up. Thus we see in the realm of organisms a ladder of emancipations—the evolution of free will.

14. **Purpose.**—The word purpose is sometimes employed to indicate use or significance, as when we ask what the purpose of that strange implement may be, but its chief usage is to indicate the intention, the anticipation, the endeavour of a living creature in any particular piece of behaviour. The wind blows the snow into wreaths which are beautifully moulded, but we do not credit the wind with purpose. The concept of purpose is irrelevant in the domain of the inorganic, unless we are thinking philosophically of the part that the development of the inorganic world has played, and is playing, in the evolution of the realm of organisms in general, and of the kingdom of man in particular. But to return to the wind playing with the snow, we do not credit it with purpose, for the result is not adaptive, there are no alternatives, there is no selection. If we knew enough about the details we could account for the whole result, perhaps without great difficulty, according to the laws of dynamics. In the same way, we do not feel it at all necessary to credit a river with purpose in its work of making the bed in which it must flow. The concept of purpose is not relevant in the domain of the inorganic.

But in the case of human life in its higher reaches, there is no possibility of making sense of it unless we recognise that conduct is often dominated by conceptual purpose. We may have our opinions as to the worth of the purpose—that is quite another question; but we cannot give an intelligible description of even relatively simple human affairs without supposing that the agents were actuated by ideas of an end to be attained.

Thus the difficulty as to when and where we may speak of Purpose narrows itself a little—to the area between man and the inorganic. It seems possible to narrow it further. For when we see a dog going off on an excursion to reinvestigate (we think) a turn of a distant road where he was yesterday disappointed of a rabbit; when we see a mother stoat, overtaken on the links, with her youngster loping beside her, take him in her mouth, race on ahead, deposit him in a scraping, and look round challengingly; when we see the rooks dropping freshwater mussels on the stones by the side of the river, and so on,—we feel that it is impossible to make sense of the facts unless we credit the creatures with at least *perceptual purposefulness.*

Without elaborating the argument, we would suggest that the term *instinctive purposiveness* be used for cases like the digger-wasps that expend so much energy on behalf of offspring that they never survive to see; and that the term *organised purposiveness* be used for cases like that, previously described, of the combat between ganglionless starfish and ganglionless sea-urchins. The question is whether we can make sense of the behaviour of the agents in these cases without the recognition of purpose, though it may be idea-less.

It goes without saying that we cannot credit with conceptual purposefulness an Amœba on the hunt (of the reality of which we should not have any doubt were we small Amœbæ with human intelligence), nor a Foraminifer with a heavy shell of sand-grains which saves itself from sinking into the ooze by building round the precise centre of a long sponge-spicule. But the question presses, whether these do not show something

analogous to purposefulness, and our verbal suggestion is that they show organised purposiveness. We propose the term purposiveness instead of purposefulness when the nature of the nervous system seems to preclude perceptual anticipation.

As a criterion of purposefulness or purposiveness in general, we suggest that there be evidence of an organismal summarising of past experience in such a way that a definite endeavour is engendered, dominating behaviour towards a result which is not immediate, this being associated with some awareness, the degree of which cannot, at present, be scientifically determined. It is quite certain that one cannot make the most of dogs or horses unless one recognises that they may have their private purposes, which must be taken account of. The difficulty is in regard to organisms below this level.

CHAPTER X

VITALITY

1. Persistence of a complex specific metabolism and of a corresponding specific organisation—2. The capacity for growth, reproduction, and development—3. Effective behaviour, registration of experience, and variability—4. Organism and mechanism—5. The uniqueness of life.

In the preceding chapters we have studied the activities of animals, and we would round off this part of the book by inquiring into the criteria of livingness, or vitality. It is plain that life may be described as a series of activities with the two chief ends of caring for self and caring for others—self-maintenance and the continuance of the race; but the more difficult question is as to the essential characteristics of the organisms that are thus active. Life may also be described as a twofold relation of action and reaction between organisms and their environment, but what we wish to make clear—though it must be tentatively—are the qualities which essentially distinguish living creatures from things in general.

1. Persistence of a Complex Specific Metabolism and of a Corresponding Specific Organisation.—The image of the organism is the burning bush of old—always afire and yet not consumed. The living creature is in ceaseless flux, always being unmade and remade. The chemical changes are pre-eminently concerned with reactions in which proteid substances play an important part. There are the two main aspects—up-building and down-breaking, synthesis and analysis, construction and disruption, assimilation and disassimilation, anabolism and katabolism; and there is more besides which cannot be readily classified in this way, for, as Sir Michael Foster

used to say, "a living body is a vortex of chemical and molecular change"; and the image of a vortex expresses the fundamental fact of persistence in spite of ceaseless change. Huxley compared the organism to the whirlpool below the Falls of Niagara, always changing, yet remaining strikingly the same year after year. Part of the secret of life is certainly that the chemical processes are so regulated and correlated that, in spite of the ceaseless change, the organism retains its integrity for days or years or centuries. And along with this must be associated two facts—that each kind of living creature has its own chemical individuality and a specific organisation. Chemically the creature is a vortex, but structurally it has an architecture, and the two are mutually conditioned. To start with, the creature is a complicated, condensed system of molecules in a colloidal state, a system with characteristic reactions and rates, which, as it lives, grows and differentiates, forms a characteristic framework or substratum. As Prof. Child suggests, the image of a stream and its bed may be useful; the stream has a character and it expresses part of its character in the bed it makes, which in turn influences the flow of the stream. The three important facts are, that there is this ceaseless metabolism, that it is specific for each kind of creature and is associated with a specific organisation, and that both are capable of persistence for a variable length of time.

2. **The Capacity for Growth, Reproduction, and Development.**—Organisms are essentially characterised by this triad of qualities, which may be usefully thought of together. (*a*) There are delicately poised, ephemeral organisms which live, to use a homely expression, from hand to mouth. They are going concerns, they balance their accounts, but they trade on a very restricted capital and cannot survive a crisis. Organisms could not have gone far if they had not had a capacity for accumulating energy, and this leads to growth. Organic growth differs from crystal growth in utilising materials quite different from those that compose the growing substance, in implying active assimilation rather than passive accre-

tion, and in being very definitely a regulated process. But growth is not to be thought of as an end or accomplishment in itself. Size as such counts for little, and the dwarf bends the Titan to his will. Growth is important because it means capital, resources, reserves; it makes trading, experimenting, adventure more possible; it facilitates differentiation on the one hand, and mastery of the medium on the other. To take a very obvious illustration, there are not a few animals, like Planarians, that can live for months on their own resources—not on nutritive reserves, but literally on themselves. But it was previous growth that made this possible.

(*b*) But growth leads on to multiplication. For, as Haeckel was one of the first to state clearly (in his *Generelle Morphologie*, 1866), reproduction is discontinuous growth. Is it possible to draw any hard-and-fast line between a fragmentation which separates off overgrowths and the more specialised forms of reproduction? It is the growth of a cell that leads to its division, though we do not know what the internal instabilities are that bring about the mysterious process. Spencer, Leuckart, and James pointed out independently that as a cell of regular shape increases in volume it does not proportionately increase in surface. If it be a sphere, the volume of material to be kept alive increases as the cube of the radius, while the surface, through which the keeping-alive is effected, increases only as the square. Thus there tends to be a hazardous disproportion between volume and surface, which may set up instability. The disturbed balance is normally restored by the cell dividing into two cells. This only leads us a little way towards understanding cell-division, but it seems clear that the correlation of chemical processes in a colloidal substratum which makes continued self-maintenance possible naturally leads on to growth, and that growth naturally leads on to division or reproduction. In any case there is nothing more distinctive of living organisms than this power of giving origin to new lives.

(*c*) It is possible, however, to take another step, logically connected with multiplication, just as multiplica-

tion is with growth, for we are led to consider development—the power that a separated part has of growing and differentiating until it has literally *reproduced* the whole. Development is the making visible of the latent potentialities—the intrinsic manifoldness—of the liberated fragment, or sample, or cell. And while the development of a fertilised egg-cell into an organism remains to us among the greatest wonders of the world, we would suggest that it may be profitably thought of as in line with the processes which are always going on to keep the specific organisation in good repair. Every gradation between the two may be found in the interesting phenomena of regeneration by which lost parts are regrown.

The three facts of growing, multiplying, and development may be thought of together under the conception of *cyclical development* which Huxley was wont to emphasise in his discussion of the characteristics of living creatures. From a microscopic egg-cell an embryo plant develops; the ovule becomes a seed, the seed a seedling; by insensible steps there is fashioned a large and varied fabric of root and stem, leaves and flowers. But no sooner has the edifice attained completeness than it begins to crumble. The grass withereth and the flower thereof fadeth, and soon there is nothing left but the seeds, which begin the cycle anew. "It is," Huxley said, "a Sisyphean process, in the course of which the living and growing plant passes from the relative simplicity and latent potentiality of the seed to the full epiphany of a highly differentiated type, thence to fall back to simplicity and potentiality again." So in the varied life-histories of animals there is usually an ascending and a descending curve from the vita minima of the egg-cell to the vita minima of senescence, or to the not less frequent terminus of violent death while the creature is still in its prime.

Behind the powers of growing, multiplying, developing, and growing again, there is perhaps the organism's unique power of accumulating energy acceleratively. As Prof. Joly has pointed out: "The transfer of energy

into any inanimate material system is attended by effects retardative to the transfer and conducive to dissipation." But the young leaf growing in the sunlight utilises the solar energy acceleratively; the more it gets, the more it grows, and the more it can take. "The transfer of energy into any animate material system is attended by effects conducive to the transfer and retardative of dissipation." On what this peculiar power depends, Prof. Joly does not tell us—that would be the secret of life; but it is interesting to get from a physicist a clear statement of the dynamic contrast between animate and inanimate material systems. "The animate system is aggressive on the energy available to it, spends it with economy and invests it with interest, till death finally deprives it of all."

3. **Effective Behaviour, Registration of Experience, and Variability.**—The common note in this triad of qualities is agency, self-expression, creativeness. (*a*) Life is a kind of activity that comes to its own in effective behaviour, that is to say, in an organically determined correlated series of acts which converge towards a definite result. Even an Amœba goes on the hunt and shows effective concatenation of activities.

(*b*) The effectiveness which is so characteristic of the behaviour of animals appears to depend on profiting by experience in the individual life-time; or on the entailed results of ancestral experiments (chiefly, perhaps, in the form of germinal variations); or, usually, on both. As W. K. Clifford said: "It is the peculiarity of living things not merely that they change under the influence of surrounding circumstances, but that any change which takes place in them is not lost, but retained, and as it were built into the organism to serve as the foundation for future actions." As Bergson puts it: "Its past, in its entirety, is prolonged into its present, and abides there, actual and acting." As Jennings says: "We know as solidly as we know anything in physiology that the history of an organism does modify it and its actions—in ways not yet thoroughly understood, doubtless, yet none the less real."

(*c*) The crowning attribute of life—and the most elusive—is variability, the organism's power of producing something new. In our present state of knowledge we can throw some light on the manner in which certain characters may be lost, or augmented, or rearranged, for there are in the history of the germ-cells many opportunities for permutations and combinations of the hereditary constituents. But the origin of the distinctively novel remains a mystery. Perhaps we must assume that organisms are essentially creative. Even the inorganic has a tendency to complexify; *a fortiori* the organic. The chemist is always turning out new carbon-compounds, the organism is in its way an inventive chemist. The same chemical substance can sometimes crystallise in more than one way—we know the variety of snow crystals; so, but with infinitely more subtlety, may the germ-cell experiment with its own architecture and trade with its environment adventurously. Just as an intact organism, from the Amœba to the Elephant, tries experiments, so the germ-cell, which is no ordinary cell, but an implicit organism, an individuality telescoped down into a one cell phase of being, may make experiments in self-expression, which we call variations or mutations. Such at least is our personal view of a great mystery. In any case, the fact of variability remains as peculiarly distinctive of organisms.

4. **Organism and Mechanism.**—A chemical and physical description can be given of much that goes on in the living body, and many great discoveries in physiology have been made by applying chemical and physical methods to the study of processes that occur in organisms. This kind of description, which is often called mechanical, will certainly continue to extend its scope, and every biologist wishes it well.

It seems, however, to many biologists that chemical and physical description is inadequate to answer the distinctively biological questions, that it does not cover the characteristic facts of life, that it is more useful in giving an account of a deposit or perhaps an eddy than in interpreting the flow of the stream.

It seems to many that no chemico-physical description has yet been given of a single vital operation, such as the contraction of a muscle, and that we cannot satisfactorily describe in mechanical terms either the linkage of events in a particular function, or the harmonising of one set of internal activities with another, or the co-ordination of acts in a piece of behaviour.

As to individual development, we cannot give a mechanical description of such facts as the condensation of the inheritance into a germ-cell, or of the differentiation of the embryo, or of the remarkable regulation-phenomena that are exhibited when an embryo rights itself after the building materials of its living edifice have been seriously disarranged, or of the way in which many developing parts seem to work into each other's hands, as if conspiring towards some distant result.

Similarly, as regards organic evolution, we cannot offer a mechanical theory of variability. Even the process of selection or sifting that goes on in Nature is more than mechanical. The evolving organism is an historical being, trading with time; and the humblest creatures are in their mutations creative. Without asking the student to accept these statements—which are rather assertions than arguments—we advise him to suspend judgment and not to be in a hurry in concluding that mechanical formulæ suffice for answering the distinctively biological questions.

5. **The Uniqueness of Life.**—When all is said there is no getting away from the big fact that living creatures are very different from things in general. They are also very different from machines, in regard to which it should be remembered that they are not fair samples of the inorganic world, having, so to speak, a human idea inside them.

(*a*) To some investigators it seems enough to say that living creatures differ from crystals and stones in their much greater complexity of architecture and of internal change. Their visible and invisible configurations and collocations are so intricate that they must be studied apart. But they do not require new formulæ or concepts for their description,

(*b*) To others it seems that living creatures have a monopoly of some peculiar physical energy or energies in a line with, say, electricity. They believe that there is evidence of the operation of this peculiar power or powers in processes like cell-division or like the differentiation of the embryo.

(*c*) More thoroughgoing is the view of the whole-hearted "vitalists," who postulate for all organisms, plants and animals alike, a non-perceptual vital agency, operating actively in certain cases, directing the chemico-physical processes, so that the results are different from what they would have been apart from intervention. The finest expression of this view is the doctrine of "Entelechy" developed by Driesch in his treatise on *The Science and Philosophy of the Organism.*

(*d*) Perhaps, however, it is safer in the meantime to be content with what may be called a descriptive or methodological vitalism, admirably stated by E. S. Russell.[1] Those who occupy this position hold that chemical and physical formulations do not suffice to answer the distinctively biological questions, do not adequately cover what is characteristic in the functions, behaviour, development, and evolution of living creatures, do not serve to exhaust the reality of the organism. Furthermore, that we require ultra-mechanical, notably *historical*, concepts for describing organisms. For the organism is a psycho-physical individuality (a mind-body or body-mind) which has enregistered within itself the gains of experience and experiment, and has ever its conative bow bent towards the future. Instead of trying to interpolate a new agency, such as "Vital Force," "Vital Principle," or "Entelechy," may we not simply recognise that in the realm of organisms there are revealed certain aspects of reality which do not at any rate assert themselves or demand to be allowed for in the domain of the inorganic?

[1] "Vitalism," *Scientia*, April 1911.

PART II

STRUCTURE AND CLASSIFICATION OF ANIMALS

CHAPTER XI

THE ELEMENTS OF STRUCTURE

1. The resemblances and contrasts between plants and animals—2. The relation of the simplest animals to those which are more complex—3. Structural analysis of the animal body: organs, tissues, cells, and protoplasm—4. Organs and organelles—5. Classification of organs—6. Correlation of organs—7. Homology, analogy, and convergence—8. Change of function—9. Substitution of organs—10. Vestigial organs—11. Adaptation in Organs

Structure and function, or form and habit, are complementary facts of life, in reality inseparable. For scientific purposes they may be studied apart, and the study of form and structure (the static relations of the organism) is called Morphology, while the study of habit and function (the dynamic relations of the organism) is called Physiology. Before passing to think of animals as regards their structure, it may be useful to compare them with plants. One reason for doing this is to make clear that the two great kinds of organisms—on the whole so very different—have a deep structural resemblance, for the bodies of both are built up of cells and transformations of cells.

1. The Resemblances and Contrasts between Plants and Animals.—Every one could point out some differences between a tree and a horse, but many might be puzzled to distinguish clearly between a sponge and a mushroom, while all have to confess their inability to draw a firm line between the simplest plants and the

simplest animals. For the tree of life is double like the letter V, with divergent branches, the ends of which, represented, let us say, by a daisy and a bird, are far apart, while the bases gradually approach and unite in a common root.

Plants and animals are alike, though not equally, alive. Diverse as are the styles of animal and vegetable architecture, the materials are virtually the same, and the individuals in both cases grow from equally simple beginnings.

Even movement, the chief characteristic of animals, occurs commonly, though in a less degree, among plants. Young shoots move round in leisurely circles, twining stems and tendrils bend and bow as they climb, leaves rise and sink, flowers open and close with the growing and waning light of day. Tendrils twine round the lightest threads, the leaves of the sensitive plant respond to a gentle touch, the tentacles of the sundew and the hairs of the fly-trap compare well with the sensitive structures of many animals. The stamens of not a few flowers move when jostled by the legs of insects, and the stigma of the musk closes on the pollen.

Plants and animals alike consist of cells or unit masses of living matter. The structure of the cell and the apparent structure of the living stuff is much the same in both. We may liken plants and animals to two analogous manufactories, both very complex; we study the raw materials which pass in, many of the stages and by-products of manufacture, and the waste which is laid aside or thrown out, but in neither case can we enter the secret room where the mystery of the process is hidden.

In the pond we find the eggs of water-snails and water-insects attached to the floating leaves of plants; in the ditches in spring we see in many places the abundant spawn of frogs and toads; we are familiar with the heavily yolk-laden eggs of birds. Now, with a little care it is quite easy to convince ourselves that an egg or ovum is to begin with a simple mass of matter, in part, at least, alive, and that by division after division the egg gives rise to a young animal. We are also well aware that in most cases the egg-cell, for cell it is, only

begins to divide after it has been penetrated, and in some subtle way stimulated, by a male unit or sperm. The great facts of individual history or development then are, the apparent simplicity in the beginning, the preliminary condition that the egg-cell be united with a male unit, and the mode of growth by repeated division of the ovum and its daughter-cells. In those plants with which we are most familiar, the facts seem different, for we watch bean and oak growing from seeds which, instead of being simple units, are very complex structures. But the seed is not the beginning of a plant, it has already a long history behind it, and when that history is traced back to the seed-box and possible seeds of the parent plant, there it will be seen that the beginning of the future herb or tree is a single cell. This is the equivalent of the animal ovum, and, like it, begins its course of repeated divisions after it has been joined by a kernel or nucleus from the pollen grain.

Thus, to sum up, along three different paths we reach the same conclusion, that there is a fundamental unity between plants and animals. In the essential activities of their life, in the stones and mortar of their structure, and lastly, in the way in which each individual begins and grows, there is a real unity. It was a very important step in the history of biology when Linnæus, perceiving the unity amid diversity, ranked animals and plants together under the common title Organisata; and it was another great step when Claude Bernard, in his *Phénomènes de la Vie Communs aux Animaux et aux Végétaux* (1878), made it clear that the two kingdoms of Organisata had, as regards their essential vital processes, a great deal in common.

Yet, after all, plants and animals *are* very different. The two kinds of organisms may be ranked as two great branches of one tree of life, yet the branches diverge widely and bear different foliage. The facts of divergence and diversity are as undeniable as the inseparable unity of the basal trunk and the genuine sameness of life throughout the whole tree. Let us state the chief contrasts between plants and animals in a tabulated summary :—

Some Exceptions	Characteristics of Animals	Characteristics of Plants	Some Exceptions
Some Protozoa and parasites simply absorb	They feed on more or less solid food	They absorb soluble food	
Some green Protozoa (etc.) seem to be able to utilise carbonic acid as plants do (holophytic).	They obtain the requisite carbon from starch, sugar, fat, etc., made by plants or by other animals	They obtain the requisite carbon from carbonic acid gas in the air or water	Carnivorous plants, fungi, and some parasites find other sources of carbon supply
Again, some Protozoa are probably able to feed like plants	They obtain the requisite nitrogen from nitrogenous compounds not simpler than proteids, made by other organisms. Most of them get rid of nitrogenous waste-products.	They obtain the requisite nitrogen from simple nitrogenous compounds, especially the nitrates of the soil. They do not get rid of nitrogenous waste-products	Again, carnivorous plants, fungi, and some parasites are in part exceptional in their nutrition
A few have green pigment very like chlorophyll-green. In most cases, however, the green colour is due to symbiotic Algæ	They have very rarely any chlorophyll	The majority possess chlorophyll, the green pigment by aid of which the living matter utilises the energy of sunlight in reducing carbonic acid (with liberation of oxygen) and in building up complex substances	Fungi and some parasites have no chlorophyll
Cellulose seems to occur in some Infusorians, and forms most of the tunic or cuticle of the passive sea-squirts or Ascidians	The component cells often have no very definite cell-walls, rarely have them of material demonstrably different from the cell-substance, and almost never show any trace of cellulose	The component cells are walled in by cellulose, a material chemically allied to starch	Some simple plants have for a time at least naked cells
	Marked division of labour among the cells is characteristic	The cells exhibit on an average much less division of labour	
	They utilise food-material already worked up by plants or by other animals; they convert this potential energy into kinetic energy in locomotion and external work; they are characteristically oxidisers, and show in their metabolism a *relative* preponderance of disruptive or katabolic processes	They build up crude, chemically simple food-material into complex substances; they convert the kinetic energy of sunlight into the potential chemical energy of these complex substances; they are characteristically reducers (of carbonic acid), expend comparatively little energy in motion or external work, are predominantly passive, and show in their metabolism a *relative* preponderance of up-building or anabolic processes	

The net result of this contrast is that animals are more active than plants. Life slumbers in the plant; it wakes and works in the animal. The changes associated with the living matter of an animal are seemingly more intense and rapid; the ratio of disruptive, power-expending changes to constructive power-accumulating changes is greater; most animals live more nearly up to their income than most plants do. They live on richer food; they take the pounds which plants have accumulated in pence, and spend them. Of course plants also expend energy, but for the most part within their own bodies; they neither toil nor spin. They stoop to conquer the elements of the inorganic world, but have comparatively little power of moving or feeling. They are more conservative and miserly than the liberally spendthrift animals, and it is possible that some of the most characteristic possessions of plants, *e.g.* cellulose, may be chemical expressions of a marked preponderance of constructive and up-building vital processes.

2. **The Relation of the Simplest Animals to those which are more Complex.**—From the pond-water catch in a glass tube one of the small animals, such as a water-flea; how does it differ from one of the simplest animals, or Protozoa? It consists of many units of living matter instead of only one. The Protozoa are single cells, all the others from sponge to man are many-celled. The Protozoa are units; all others—the Metazoa—are composite aggregates of units, or cities of cells. But since the Protozoa are complete organisms, often intricate in structure and behaviour, it may be more accurate to call them *non-cellular*.

Compare the life of one of the Protozoa with that of a worm, a frog, or a bird. Both are alive, both may be seen moving, shrinking away from what is hurtful, drawing near to what is useful, engulfing food, and getting rid of refuse. Both are breathing, for carbonic acid will poison them, and dearth of oxygen will kill them; both grow and multiply. But in the single-celled Protozoon all the processes of life occur within a unit mass of living matter. In the many-celled Metazoon the various pro-

cesses occur at different parts of the body, are discharged by special sets of cells, among which the labour of life has been divided. The life of the Protozoon is like that of a one-roomed house which is at once kitchen and work-room, nursery and coal-cellar. The life of the Metazoon is like that of a mansion where there are special rooms for diverse purposes.

Protozoa multiply by dividing into two daughter-units (fission), or by budding, or by dividing repeatedly within a cyst or envelope so that numerous minute units result (spore-formation). Apart from these modes of multiplication, there is a frequent recurrence of conjugation, which is remotely analogous to fertilisation in higher animals. Two Protozoa, equal or unequal in size, similar or dissimilar in appearance, may unite to become one (total conjugation), or two apparently similar individuals may be closely apposed, exchange portions of their nucleus and separate again (partial conjugation). This has been much studied in ciliated Infusorians.

In having no " body " the Protozoa are to some extent relieved from the necessity of death. Within the compass of a single cell they perform a crowd of functions, but wear and tear are often made good again, the units have great power of self-recuperation. They may, indeed, be crushed to powder, and they lead no charmed life safe from the appetite of higher forms. But these are violent deaths, and the same term may be applied to the huge mortality among open-sea Protozoa, which seem often to be killed in enormous numbers by sudden changes of temperature and the like. What Weismann and others have insisted on is that the unicellular Protozoa, in natural conditions, need never die a natural death, being in that sense immortal. It is true that a Protozoon may multiply by dividing into two or more parts, but only a sort of metaphysical individuality is thus lost, and there is nothing left to bury.

In connection with this " immortality of the Protozoa " it should be noticed that an isolated family of Infusorians multiplying asexually (by dividing into two) for hundreds of successive generations usually comes to an end after

a period of extraordinary senility. This may be avoided by taking great precautions to keep up the food-supply and to remove waste-products. In certain cases the senility of the race of Infusorians can be staved off for a time by using appropriate stimulants, such as beef-tea, and very perfect nutritive media have been discovered in the course of experiment. In a stock all descended by asexual multiplication from one ancestor there is no conjugation—probably because they are all practically identical. It has been supposed by some that the absence of conjugation is in itself the cause of the decadence of the stock, but it seems more likely that the function of conjugation is to promote variability. In natural conditions this variability may enable a strain to parry successfully some change in the environment.

The combination of all the vital activities within the compass of a single cell involves a very complex life within the unit,—not more complex than the entire life of a many-celled animal, but fuller than that of one of its component cells. While a Protozoon is relatively simple in structure, its life of crowded functions, such as moving, digesting, breathing, is exceedingly complex. The simpler an organism is in structure the more difficult will it be to study its separate functions. Physiological or functional simplicity is in inverse ratio to structural or morphological simplicity. Thus the physiologist makes most progress when he seeks to understand animals with many parts, for there he can find a large number of units, all as it were working at one task. The life of a Protozoon is more manifold and complex than that of any unit from a higher animal, just as the daily life of the savage—at once hunter, shepherd, warrior—is more varied than ours.

Every many-celled animal, if it is reproduced in the ordinary way, begins its life as a single cell,—as an egg-cell with which a male element has united. Thus it may be said that every Metazoon begins its life at the level of a Protozoon, and this is true even of very large animals, for the whales arise from ova "no larger than

fern-seed," and even of the highest, for man himself has to begin his life at the one-cell beginning. The fertilised egg-cell divides and re-divides, its daughter-cells also divide, the resultant units are arranged in layers, woven together to form tissues, compacted to form young organs, and the result is such a multicellular body as we possess; but while this body-making proceeds, certain units are kept apart, in some way insulated from the process of development, to form the future reproductive elements, which, freed from the adult body, will begin a new generation. The contrast, then, is this, that the Protozoa may be compared to the germ-cells of the Metazoa; while the daughter cells into which a Protozoon divides separate from one another, the divided cells of the fertilised ovum cohere to form a young animal.

The gulf between the single-celled and many-celled animals is a deep one, but it has been bridged. Otherwise we should not exist. Traces of the bridge now remain in what are called "colonial Protozoa," which, however troublesome to those who like crisp distinctions, are most instructive to those who would appreciate the continuity of the tree of life. These exceptional Protozoa are loose colonies of cells, daughter-cells of a parent unit, which have remained persistently associated instead of going free with the usual individualism of Protozoa. They show us how the Metazoa or multicellular animals may have arisen.

3. **Structural Analysis of the Body.**—The outer *form* of normal animals seems to be always artistically harmonious. There may be some ugliness in the lines and colours of diseased animals, of domesticated animals which man has exaggerated in some particular direction such as fatness, of degenerate parasites which have ceased to live an independent life, and of the unfinished ante-natal stages of some animals, but beauty is the rule. All free-living, finished, healthy animals in their natural environment give us æsthetic pleasure, unless we are unable to overcome prejudice—against snakes, for instance. Beauty is the stamp of a harmonious unity, of a well-balanced individuality which has stood the test

of time. As Meredith says: "Ugly is only half-way to a thing." But those who have not already perceived this will not see much meaning in the assertion, nor in Samuel Butler's opinion that "form is mind made manifest in flesh through action," nor in Walt Whitman's eulogy:

> "I believe a leaf of grass is no less than the journey-work of the stars,
> And the pismire is equally perfect, and the grain of sand, and the egg of the wren,
> And the tree-toad is a chef-d'œuvre for the highest,
> And the running blackberry would adorn the parlours of heaven,
> And the narrowest hinge in my hand puts to scorn all machinery,
> And the cow crunching with depressed head surpasses any statue,
> And a mouse is miracle enough to stagger sextillions of infidels!"

Apart from artistic considerations, there is much that interests us in the outsides of animals. We can readily understand that the radial symmetry of sea-anemones and jellyfishes is well adapted for a sedentary or for a drifting mode of life, while bilateral symmetry, with a head-end and a tail-end, with a right-side and a left-side, and one median dorso-ventral halving plane is suited for a more active and assertive life, for pursuing prey and mates, or for avoiding enemies. It was one of the greatest steps in organic evolution when animals, probably some worm-types to start with, began the habit of moving with one end of the body always in front. As Prof. Hickson points out, there appears to be greater plasticity or variability of architectural detail in the radially symmetrical, especially when colonies are formed, and greater specific individuality and architectural constancy in the bilateral.

When we press below the surface of the animal we begin what is called structural analysis. We have to distinguish great systems of parts, such as the skeletal system, the muscular system, the nervous system. We have to identify great organs, such as brain, heart, lungs, and liver. We analyse further and find that these are built up of tissues, such as muscular, nervous, connective, and glandular tissues. With the high power of the

microscope we find that these are composed of many cells, which may be defined as unit-masses or unit-areas of living matter each centred in a nucleus.

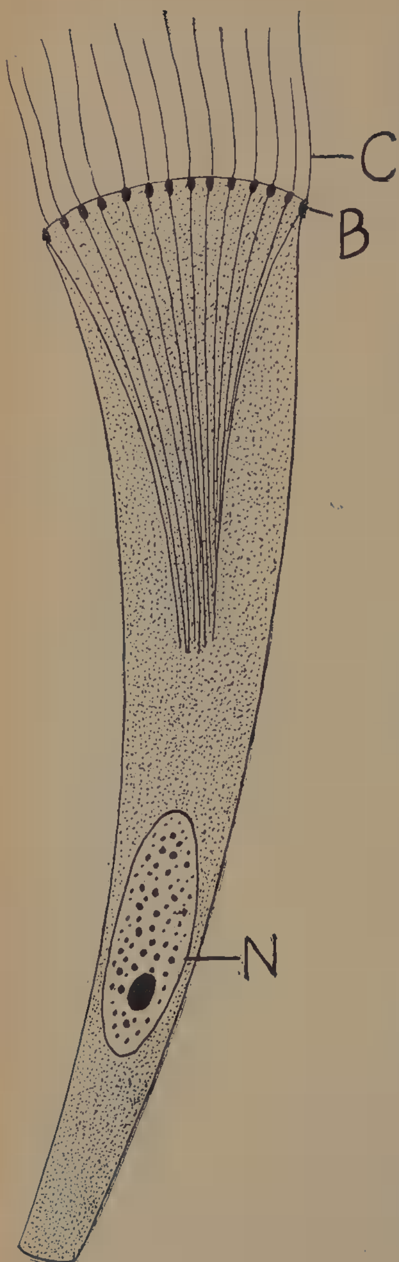
Corresponding to this morphological analysis there is a physiological analysis which does not concern us at present. But the general parallelism should be noted. Just as the morphologist begins with the form of the whole animal, so the physiologist begins with the intact animal as a unity with habits and temperaments. He goes on to consider it as an engine made up of organs, as an intricate fabric of tissues, as a city of cells, and as a strangely unified whirlpool of living matter.

With the school of Cuvier we associate the beginning of a masterly comparative study of the organs of animals; and it is with the name of Bichât (whose *Anatomie Générale* was published in 1801) that we associate the first vigorous analysis of organs into tissues. If we take the next step of analysis, and think of the body as a complex city of cells, we are better able to understand what tissues are. Each cell corresponds to a house, a tissue corresponds to a street of similar houses. In some cities we see homogeneous streets of similar shops, one street devoted to bread-making, another to boot-making. So in the animal body aggregates of contractile cells form muscular tissue, of supporting cells skeletal tissue, of secreting cells glandular tissue, and so on.

It must suffice to state the general idea that a tissue is an aggregate of more or less similar cells, and to note that the different kinds may be grouped as follows:—

I. Nervous tissue, consisting of cells which receive, transmit, or originate nerve-stimuli.
II. Muscular tissue, consisting of contractile cells.
III. Epithelial tissue, consisting of lining and covering cells, which often become glandular, exuding the products of their activity as secretions.
IV. Connective tissue, including cells which bind, support, and store.

Cells.—To the discovery and perfecting of the microscope we owe the analysis of the body into its unit masses



of living matter or cells. From 1838-39, when Schwann and Schleiden stated in their "cell doctrine" that all organisms—plants and animals alike—were built up of cells, cellular biology may be said to date. It was soon shown as a corollary that every organism which is reproduced in the ordinary fashion arises from a single egg-cell or ovum which has been

FIG. 51.—A SINGLE CELL OF CILIATED EPITHELIUM TO ILLUSTRATE A LITTLE OF THE COMPLEXITY THAT THERE MAY BE IN CELLS.

(After Schneider.)

At the roots of the cilia (*C*) there are basal corpuscles (*B*), and from these there are fine root-threads extending far into the cell. The nucleus (*N*) shows a nucleolus and small chromatin granules. The cytoplasm is shaded with dots.

fertilised by union with a male-cell or spermatozoon.

Now, the cells of the animal body are necessarily varied, for the existence of a body involves division of labour among the units. Some, such as the ciliated cells lining the windpipe, are very active, like the Infusorian Protozoa; others, for instance fat-cells and gristle-cells, are very passive, something like the Gregarines; others, such as

the white blood corpuscles or leucocytes, are between these extremes, and resemble the amœboid Protozoa.

But it is true of most of them that they consist (1) of a complex, and in part living cell-substance, in which keen eyes looking through good microscopes detect an intricate network, or sometimes the appearance of a fine foam;

FIG. 52.—DRAWING OF A MODEL OF A CELL.

N is the spherical nucleus, containing two coiled chromosomes (*CHR*), one of which shows a thickening of chromatin.

To the left are two centrosomes (*C*), with fine radiating filaments around each and between them.

The general cell-substance or cytoplasm (*CY*) shows a complicated reticular structure. There are several vacuoles (*V*).

What is called a chromidial apparatus (*CH*) consists of chromatin granules which appear to have passed from the nucleus into the cytoplasm.

There are also two groups of mitochondria (*M*), formed bodies in the cytoplasm which are connected with particular functions of the cell.

(2) of a central kernel or nucleus, which plays an essential part in the life of the cell and contains a little world in itself—of "chromosomes" and other bodies; (3) of a slight outer membrane, varying much in definiteness

and sometimes quite absent, through which communications with neighbouring cells are often established; and (4) of non-living cell contents, products of the vital activity such as pigment and fat. Most animal cells also contain a centrosome which plays an important part during cell-division. The general cell-substance or cytoplasm is sometimes, as it were, colonised, by minute structures of nuclear origin called chromidia, made of

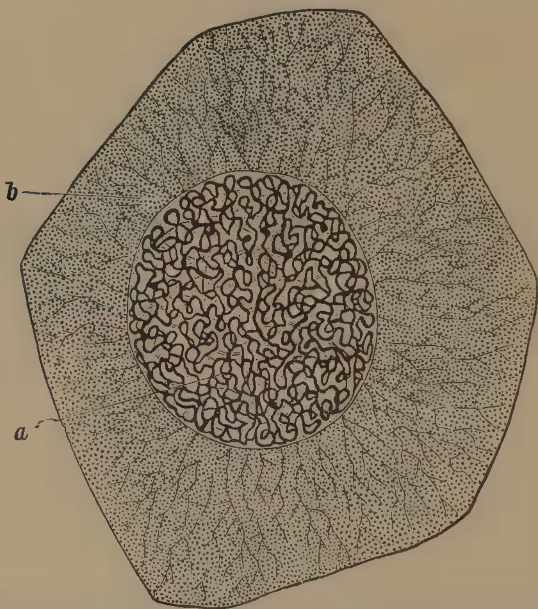


FIG. 53.—ANIMAL CELL, SHOWING THE COILED CHROMATIN THREADS OF THE NUCLEUS (*a*), AND THE PROTOPLASMIC NETWORK (*b*) ROUND ABOUT. (From *Evolution of Sex*; after Carnoy.)

material comparable to the chromatin of the chromosomes of the nucleus. Moreover, the cytoplasm often shows specialised bodies called mitochondria which are connected with particular cellular functions, such as secretion. These things are mentioned so as to give at least a hint of the extraordinary complexity of structure that there often is in a cell much smaller than a pin-prick.

Two very interesting general facts in regard to the

cells that build up the body of an animal may be briefly noticed. The first is that in some cases there is great definiteness in the number and position of the cells building up the body; thus in the Rotifer *Hydatina senta* there are 959 cells in the body, and each has its proper place. The second fact is that there is often remarkable definiteness in corresponding cells in different animals, so that those of one type could not be confused with those of another. Thus the ciliated epithelial cells lining the windpipe of a horse are different from those in the same place in a dog. This is called "specificity," and it means that each particular type has an individuality or idiosyncrasy of its own, and that this is demonstrable in great detail.

The growth of all multicellular animals depends upon a multiplication of the component cells. Like organisms, cells have definite limits of growth which they rarely exceed; giants among the units are rare. When the limit of growth is reached the cell divides.

The necessity for this division, as indicated by Spencer, Leuckart, and James, has been already referred to. But we wish to dwell on it. If you take a round lump of dough weighing an ounce, another of two ounces, a third of four ounces, you obviously have three masses successively doubled, but in doubling the mass you have not doubled the surface. The mass increases as the cube, the surface only as the square of the radius. Suppose these lumps alive, the second has twice as much living matter as the first, but not twice the surface. Yet it is through the surface that the living matter is fed, aerated, and purified. The unit will therefore get into physiological difficulties as it grows bigger, because its increase of surface does not keep pace with its increase of mass. Its waste tends to exceed its repair, its expenditure gains on its income. What are the alternatives? It may go on growing and die (but this is not likely); it may cease growing at the fit limit; it may greatly increase its surface by outflowing processes (which thus may be regarded as life-saving); or it may divide. The last is the usual course. When the unit has grown as large as

it can conveniently grow, it divides; in other words, it reproduces at the limit of growth, when processes of waste are gaining on those of repair. By dividing, the mass is lessened, the surface increased, the life continued.

But although we thus get a general rationale of cell-division, we are not nearer a conception of the internal forces which operate when a cell divides. In most cases the process is orderly and complex, and is somehow governed by the behaviour of the nucleus. Few results of the modern study of minute structure are more marvellous than those which relate to dividing cells. From Protozoa to man, and also in plants, the process is in its essentials strikingly uniform. The nucleus of the cell loses its membrane; the centrosome divides into two and one lies at each pole; the coil of chromatin threads becomes resolved into a definite number of rod-like chromosomes; these become arranged on the equatorial plane and each is longitudinally cleft in two; one half of each goes to one pole, the other half to the other; the cell is divided across the equator; and there is a reconstruction of the daughter-nuclei in the two cells which thus arise from one. The division is most thorough, each of the two daughter-cells getting an accurate half of the original nucleus. (See Fig. 54.)

We study the nucleus, first as a simple kernel which divides, years afterwards as composed of a network or coil of nuclear threads; later still as a focus of chromosomes which seem ever to become more marvellous, "behaving like little organisms." After all our analysis, both chemical and physical, we are baffled by the movements of the protoplasm, the cycle of phases in the nucleus, the behaviour of the centrosomes, the manœuvres of the chromosomes; indeed in regard to the whole give and take, combination and opposition, among the many members of the "cell-firm," as we may well call it, we must admit that they behave as they do because they are alive.

From the cell as a unit element we pass in our structural analysis to the protoplasm itself, the physical basis of life; and the important general fact is simply that

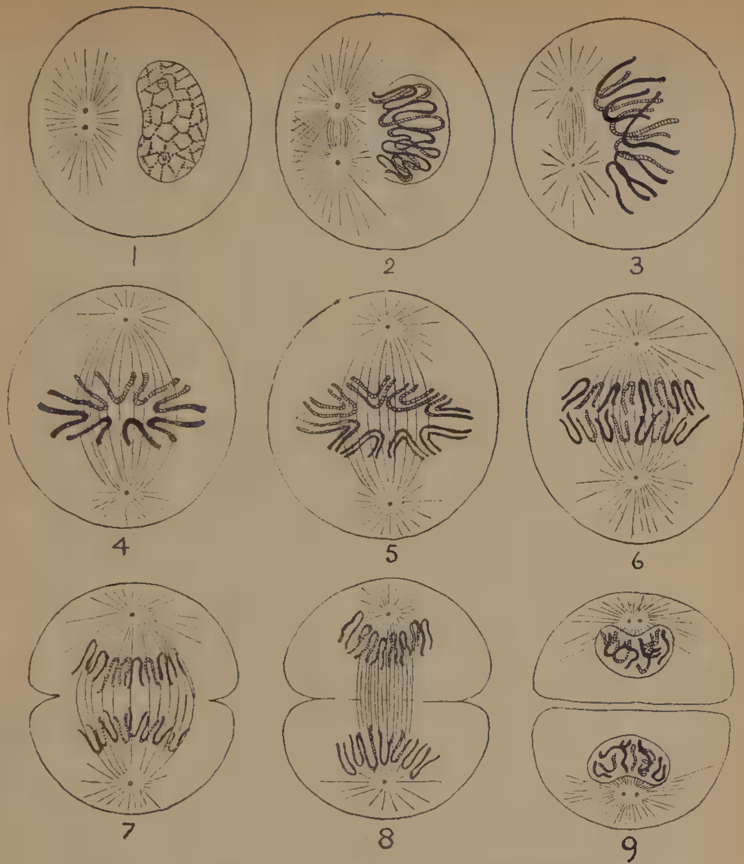


FIG. 54.—CELL-DIVISION. (After Rauber-Kopsch).

Fig. 1 shows a cell before the process of nuclear division has quite begun. The chromatin in the nucleus is in the form of a network. The centrosome has divided into two and is surrounded by very delicate radiating filaments.

Fig. 2. The chromatin reticulum is being unravelled into a number of chromosomes and the nuclear membrane is giving way. The centrosomes are separating.

Fig. 3. The nuclear membrane is gone, the chromosomes are more distinct.

Fig, 4. The chromosomes are arranged (in an astroid) on the equatorial plane in the middle of the cell. There is a centrosome at each pole, and a nuclear spindle of fine threads between. Some threads run from pole to pole. Some are attached to chromosomes at the equator. The changes up to this point constitute the *prophases.*

Fig. 5. Each chromosome is split lengthwise. (*Metakinesis.*)

Fig. 6. The chromosomes form a diastroid figure and there is a movement towards the pole. In each contingent there is one half of each chromosome.

Fig. 7. The chromosomes continue to move from the equator. The cell-substance begins to be divided.

Fig. 8. At each pole a daughter nucleus begins to be constituted. A partition is formed across the equator of the cell.

Fig. 9. There are now two cells, and the daughter-nuclei are passing into a resting phase. The centrosome has again become paired. The changes after the splitting of the chromosomes and on to reconstruction constitute the *anaphases.*

the cell-substance or cytoplasm has in most cases a definite structure, a microscopically minute organisation. It is very different from white of egg, which is homogeneous and structureless. Sometimes it appears like a network, sometimes like a fine emulsion; and it may exhibit a visibly different structure in different kinds of organisms. Often it is possible, especially by the use of staining and fixing re-agents, to distinguish a relatively

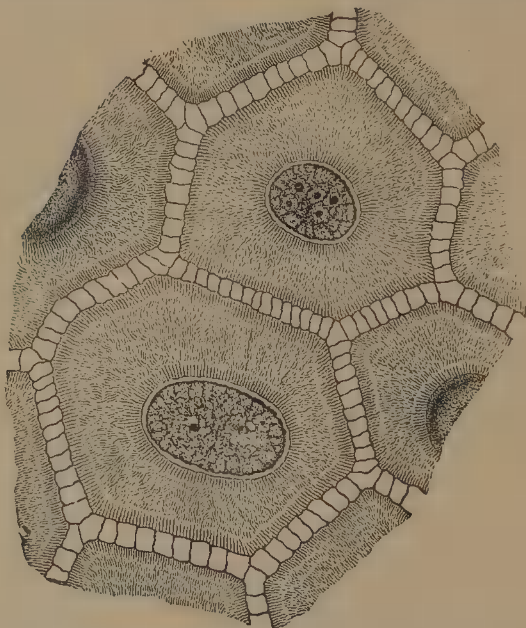


FIG. 55.—ADJACENT ANIMAL CELLS SHOWING THE NUCLEUS, THE PROTOPLASMIC NETWORK, AND THE BRIDGES VITALLY UNITING CELL AND CELL ACROSS THE INTERVENING INTER-CELLULAR SUBSTANCE. (From the *Evolution of Sex*; after Pfitzner.)

more stable framework and a relatively more changeful or labile material within the meshes.

4. **Organs and Organelles.**—In unicellular animals there is often much structural complexity. There may be locomotor cilia or flagella, offensive threads or trichocysts, contractile fibrils, adhesive suckers, pulsating vacuoles, and so forth, and it is convenient to have some term for these, since they are not organs in the sense

in which we use the word in reference to the parts of multicellular animals. The term organelle may be kept for the specialised parts of a Protozoon or of a cell, leaving the word organ for the specialised parts, composed of many cells, in Metazoa. (See Fig. 51.)

Organs are well-defined parts, such as limb or liver, heart or brain, in which there is a predominance of one or a few kinds of vital activity. It is gradually that they take form and function in the individual; and the same must be true of their racial evolution. There is contractility before there are definite contractile organs and muscles; there is diffuse sensitiveness before there are defined nerves and sense-organs. The progress of structure, alike in the individual and in the race, is from simplicity to complexity, as the progress of function is from homogeneous diffuseness to heterogeneous specialisation. The two great kinds of progress may be illustrated by contrasting a sea-anemone and a bird. The higher animal has more numerous parts or organs, the division of labour within its body has brought about more differentiation of structure, but it is also a more perfect unity, its parts are more thoroughly knit together and harmonised. There is progress in integration as well as in differentiation.

"The shoulder-girdle of the skate," W. K. Parker says, "may be compared to a clay model in its first stages, or to the heavy oaken furniture of our forefathers that stood ponderous and fixed by its own massy weight. As we ascend the vertebrate scale, the mass becomes more elegant, more subdivided, and more metamorphosed, until, in the bird class and among mammals, these parts form the framework of limbs than which nothing can be imagined more agile or more apt. So also as regards the sternum; at first a mere outcrop of the feebly developed costal arches in the amphibia, it becomes the keystone of perfect arches in the true reptiles, then the fulcrum of exquisitely constructed organs of flight in the bird; and lastly, forms the mobile front wall of the heaving chest of the highest vertebrate."

5. **Classification of Organs.**—We may arrange organs according to their work, some, such as limbs and weapons, being busied with the external relations of the organism; others, such as heart and liver, being concerned with

internal affairs. Or we may classify them according to their development from the outer, middle, or inner layer of the embryo. Thus the brain and the essential parts of the sense-organs are due to the outer ectoderm or epiblast; muscles and skeleton arise from the middle mesoderm or mesoblast; the gut and its outgrowths such as lungs and liver originate from the inner endoderm or hypoblast. Or we may arrange the various structures more or less arbitrarily for convenience of description as follows: the skin and its outgrowths, appendages, skeleton, muscular system, nervous system, sense-organs, the food-canal and its outgrowths, the body-cavity, the heart and blood-vessels, the respiratory organs, the excretory system, the reproductive organs.

Of the *order in which organs appear* or have appeared we can say little. The simplest sponges and polypes are little more than two-layered cups of cells, the cavity of the cup being the primitive food-canal. A parallel stage occurs in the early life-history of most animals, when the embryo has the form of a two-layered sac of cells, *i.e.* in technical language, a gastrula. Both in the racial and individual life-history the formation of this primitive food-canal occurs very early. But it is not certain that it—the primitive stomach—was not at a still earlier stage an internal brood-cavity!

6. **Correlation of Organs.**—One of the most fundamental facts about organs is their correlation. They are members one of another, they stand or fall together, they are physiologically knit, they have been evolved in company. Thus heart and lungs, muscles and nerves, are closely correlated. Sometimes it is obvious why two or three structures should be thus connected, for it is of the very essence of an organism that its parts are members one of another. In other cases the reason of the connection is obscure. Influences pass from one organ to another by the nervous system. Thus a digestive disturbance may affect the eye or the heart. Or the influence may be conveyed chemically by the blood, and of great importance in this connection are the "internal secretions" or hormones which are produced by duct-

less glands, like the thyroid gland and the adrenal body, and are distributed through the body by the blood, often affecting distant parts in a very specific way. From the anatomical or morphological point of view, however, we mean by the correlation of organs more especially the fact that certain structures have been linked together in the course of evolution. Thus no mammal chews the cud that is not an even-toed Ungulate; no animal that has an allantois has gills.

7. **Homology, Analogy, and Convergence.**—When organs either in the same or in different animals have a similar development, and are built up on the same architectural plan, they are called *homologous*. Those whose resemblance is merely that they have similar functions are termed *analogous*. Even Aristotle recognised that some structures apparently different were fundamentally the same, and no small part of the progress of morphology has consisted in the recognition of homologies. Thus it was a great step when Goethe and others showed that the sepals, petals, stamens, and carpels of a flower were really transformed leaves, or when Savigny discerned that the three pairs of jaws beside an insect's mouth were really transformed legs. To Owen the precision of our conceptions in regard to homologies is in great part due, though subsequent studies in development have added welcome corroboration to many of the comparisons which formerly were based solely on the results of anatomy. Thus an organ derived from the outer embryonic layer (or ectoderm) cannot be homologous with one derived from the inner layer (or endoderm). Homologous organs in one animal are well illustrated by the nineteen pairs of appendages borne by a crayfish or lobster. These differ greatly in form and in function; many of them are not analogous with their neighbours, one feels and another bites, one seizes and another swims, but they are all homologous. So are the different forms of fore-limb, the pectoral fin of a fish, the fore-leg of a frog or lizard, the wing of a bird, the flipper of a whale, the fore-leg of a tiger, the arm of man. But the wing of an insect is merely ana-

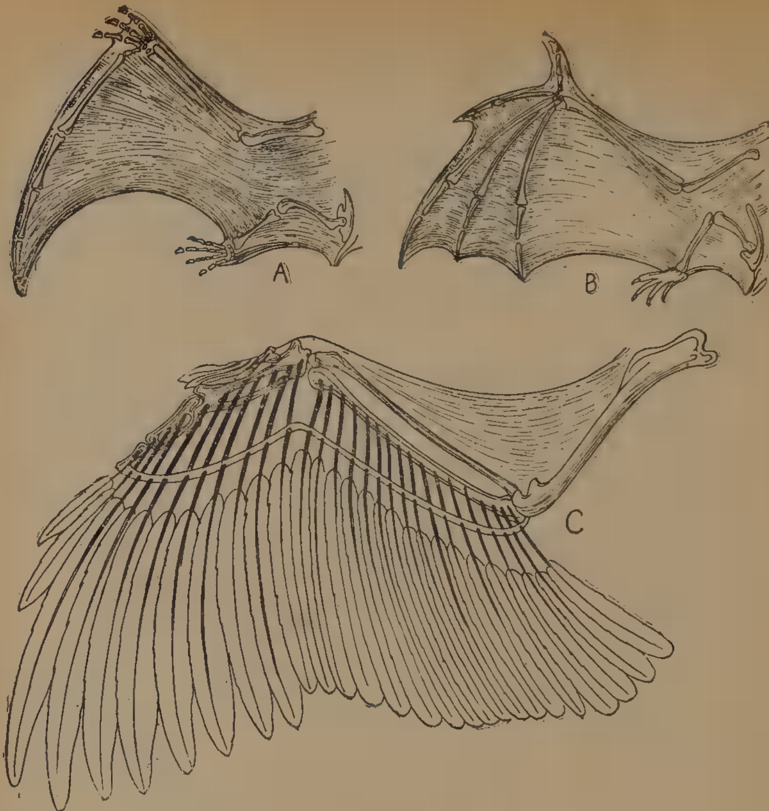


FIG. 56.—THREE KINDS OF WINGS.

A. The wing and associated parts of an extinct flying reptile, a Pterodactyl or Pterosaur. An extension of skin, the mark of which is seen on some of the fossils, was held out by the arm and mainly by the greatly elongated outermost finger. The first digit is rudimentary or absent, so the one which is exaggerated is "the little finger," No. V. Thence the skin or patagium was continued to the hind leg and even to the tail.

B. The wing and associated parts of a bat. The extension of skin or patagium begins at the side of the neck, passes along the upper side of the arm to the wrist, practically skips the thumb, is continued between the four fingers and thence down the side of the body to the hind leg, and between the legs to the tail, if there is one.

C. The wing of a bird. In front there is a small patagium from the upper arm to the wrist, but the surface for striking the air, which was gained in the other forms by the skin, is here due to the feathers. A small tuft, the ala spuria, is attached to the thumb. The longest feathers, the primaries, are fastened to a fused bone called the carpo-metacarpus (due to a coalescence of three wrist-bones or carpals and three palm-bones or metacarpals). The other feath rs shown, the secondaries, are attached to the ulna, the outer surface of which shows a row of tuberosities where the muscles which move the individual feathers a little are inserted. Besides the feathers shown, there are smaller wing-coverts above and below.

These three flying structures are analogous. The bird's wing is homologous with the anterior part—the arm part—of the flying apparatus of the two others. Some believe that birds had originally a posterior patagium from the upper part of the leg to the tail, which once was long.

logous not homologous with that of a bird, while the wings of bats and birds are both analogous and homologous.

When two animals not nearly related to one another live in similar conditions they often show a superficial resemblance, being similarly adapted to the circumstances of the case. Such resemblance is technically called *convergence* or *homoplasty*. It is due to similar

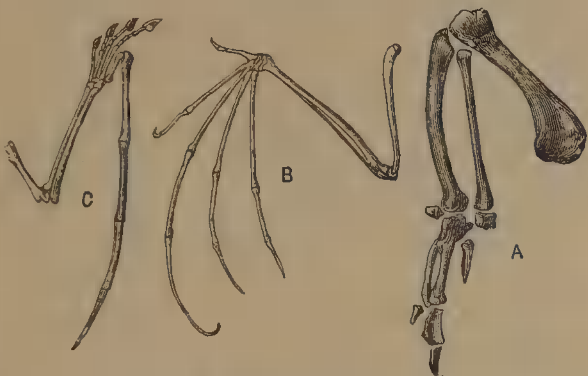


FIG. 57.—BONES OF THE WING IN PIGEON (*A*), BAT (*B*), EXTINCT PTERODACTYL (*C*).

(From Chambers's *Encyclop.*)

The student should notice in *A* the two free wrist-bones or carpals; the fused carpo-metacarpus; the thumb with one joint, in a line with the more slender of the fore-arm bones—the radius; the first finger with two joints; the second finger with one joint. The thicker of the fore-arm bones is the ulna; it is an incomplete splint in the bat's wing.

In *B* the palm-bones (metacarpals) of the fingers are long and free; the fingers have only two joints or phalanges; claws are confined to the thumb and first finger, or to the thumb only. It is instructive to become familiar with the differences, at almost every point, between the bird's wing and the bat's wing. Yet they are thoroughly homologous as well as analogous.

In *C* the thumb is drawn much too large. It is usually unrepresented and is at most minute. The enormously elongated outermost or ulnar digit corresponds to our little finger.

adaptations of parts and does not indicate, as homology does, any blood-relationship. A burrowing amphibian (a Cæcilian), a burrowing lizard (an Amphisbænid or a slow-worm), and a burrowing snake (a Typhlopid) are very like one another externally, but that is because they are similarly adapted to burrowing. They are not at all like one another internally. Similarly a Cetacean shows a slight superficial convergence to a fish. Or, to

take a particular case, the skull of a carnivorous marsupial, such as a Tasmanian Devil, shows many convergent or homoplastic resemblances to the skull of one of the Carnivora, such as a dog.

8. **Change of Function.**—Organs are not mechanisms rigidly adapted for only one purpose. In many cases they have a main function and several subsidiary functions, and changes may take place in organs by the occasional predominance of a subsidiary function over the original primary one. Dr. Anton Dohrn, the founder of the Naples Zoological Station, especially emphasised the idea of function-change. He wrote :—

> "Every function is the resultant of several components, of which one is the chief or primary function, while the others are subsidiary or secondary. The diminution of the chief function and the accession of a secondary function changes the total function; the secondary function becomes gradually the chief one; the result is the modification of the organ."

The contraction of a muscle is always accompanied by electric changes, and in the electric organs of the Torpedo and some other fishes that give a shock, the electric changes in the modified muscular tissue composing the organ have become more important than the contractility. The swim- or air-bladder which grows out dorsally from the food-canal of most fishes, seems usually to be a hydrostatic organ; in a few cases it helps slightly in respiration, but in the double-breathing mud-fishes or Dipnoi it has become a genuine lung. An unimportant (allantoic) bladder at the hind end of the gut in frogs, is represented in the embryos of reptiles and birds by a very important respiratory (and sometimes yolk-absorbing) birthrobe, and in almost all mammals by part of the placenta which unites mother and unborn offspring.

We seem to have here a disclosure of one of the methods of organic evolution—that apparently novel things are often rehabilitations of very old structures. The elephant's trunk was a novelty in its day (though it evolved gradually enough), but it is, after all, little more than

a consummate nose. The spinnerets of spiders are exquisite contrivances for the issue of jets of liquid silk, but they are morphologically equivalent to two or three pairs of abdominal limbs, and it is instructive to notice that the embryo spider has three or four other pairs of abdominal appendages which do not become limbs in the adult. The sting of a bee is a specialised ovipositor (and therefore unrepresented in the drone); the fang of a venomous snake is a tooth folded so as to enclose a canal, and the bag of poison is an evolved salivary or labial gland. The Eustachian tube which extends from the tympanic cavity of the ear to the back of the mouth is but a transformed and persistent gill-cleft (the spiracle of the skate), and the three-linked chain of ossicles which convey vibrations from the drum or tympanum to the internal organ of hearing was once in whole or in part included in the commonplace framework of the jaws.

9. **Substitution of Organs.**—To the embryologist Kleinenberg we owe a suggestive conception of organic change, which he spoke of as the development of organs by substitution: An organ may supply the stimulus and the necessary condition for another which gradually supersedes and replaces it. In the simplest backboned animals, such as the lancelet, there is a supporting skeletal rod along the back; among fishes the same rod or notochord is largely replaced by a backbone; in yet higher Vertebrates the adults have almost no vestige of notochord, its replacement by the backbone is almost complete. So in the individual life-history, all vertebrate embryos have a notochord to begin with; in the lancelet and some others this is retained throughout life, in higher forms it is temporary and serves as a scaffolding around which, from a thoroughly distinct embryological origin, the backbone develops. What is the relation between these two structures—notochord and backbone? According to Kleinenberg, the notochord supplies the necessary stimulus or condition for the development of the backbone which replaces it.

The general idea of one organ leading on to another is suggestive. It is consistent with our general conception

of development—that each stage supplies the necessary stimulus for the next step; it also helps us to understand more clearly how new structures, too incipient to be of use, might be fostered by old-established structures with which they are associated, and why old structures should linger though they have not any longer more than a transitory importance.

10. **Vestigial Organs.**—(*a*) Through some ingrained defect it sometimes happens that an organ does not develop perfectly. The heart, the brain, the eye may be spoilt in the making. Such cases are illustrations of arrested development. (*b*) A parasitic crustacean, such as the *Sacculina* which shelters beneath the tail of a crab, begins life with many equipments such as legs, food-canal, eye, and brain, which are afterwards entirely or nearly lost; the sedentary adult sea-squirt or ascidian has lost the tail, the notochord, the spinal cord which its free-swimming tadpole-like larva possessed. Such cases are illustrations of degeneration. (*c*) In these instances the retrogression is demonstrable in each lifetime, in other cases we have to compare the animal with its ancestral ideal. Thus there are many cave-animals whose eyes are always blind and abortive. The little kiwi of New Zealand has only apologies for wings. We need have no hesitation in calling these animals degenerate in eyes and fore-limbs respectively. (*d*) But somewhat different are such structures as the following: the embryonic gill-clefts of reptiles, birds, and mammals, which have no respiratory significance, or the embryonic teeth of whalebone whales, which never come to anything. They are vestigial structures, which are partly explained on the assumption, justified also in other ways, that the ancestors of reptiles, birds, and mammals used the gill-clefts as fishes and tadpoles do, that the ancestors of whalebone whales had functional teeth. Darwin compared them to unsounded letters in words, like the "o" in leopard or the "b" in doubt. They remain as parts of the inheritance which have survived their utility. It should be noted, however, that some of them may be useful in connection with the development of other structures.

When old-fashioned structures are turned to new uses, as in the case already mentioned of the first gill-cleft becoming the Eustachian tube, the term vestigial should not be used, unless it be carefully qualified. Vestigial structures in the strict sense are structures which linger on in dwindled expression for ages after they have ceased to be of use. They have often been compared to the vestigial structures in clothes, buttons that have no corresponding buttonholes, and holes that have no corresponding buttons.

Some of the Cetaceans show deeply buried remnants of a hip-girdle and even of the upper part of the leg,—remnants that are in certain cases very variable, as vestigial organs are apt to be. In the spiracle of the skate (see fig. 86) there is a minute vestige of a lost gill; the spiracle is in no sense a vestige, but the comb-like ridge is. Of vestigial structures in man much has been said, and Prof. Wiedersheim has brought the facts together in his striking book, *The Structure of Man, an Index to his Past History*. He shows that we are antiquarians even if we are unaware of it, and walking museums of relics. In the median corner of the eye lies the vestigial third eyelid, larger in some races than in others, and sometimes with a minute supporting cartilage. Now, this third eyelid or nictitating membrane is present and well-developed in most mammals, not to speak of birds and reptiles; it is a useful structure which cleans the front of the eye-ball when it is flicked across. It is absent in Cetaceans, where the eye is continually washed; it is vestigial in apes and in man, where the mobility of the upper eyelid has rendered the retention of the extra structure unnecessary. Similarly, the muscle which moves the trumpet or pinna of the ear in many mammals, such as dog and donkey, is vestigial in man, though some have it larger than others and can even call it into activity by wasting sufficient attention on the senseless effort.

11. **Adaptation in Organs.**—One of the outstanding impressions that we get from the study of structure is that of adaptiveness. The structure is always so admir-

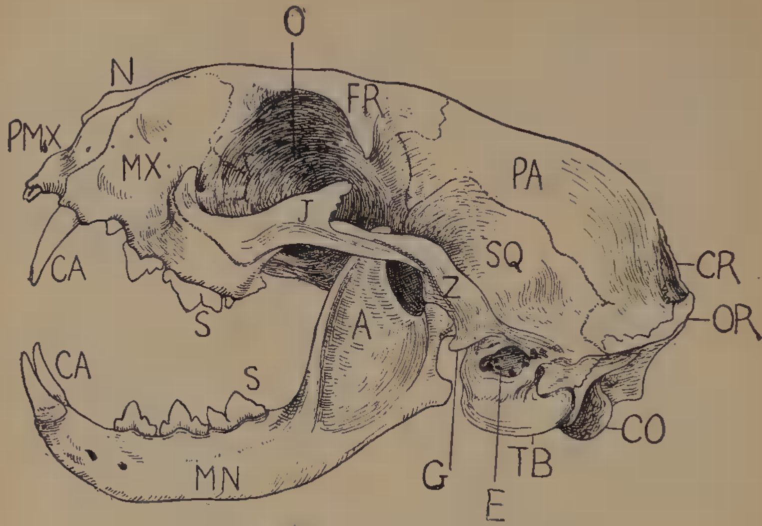


FIG. 58.—THE SKULL OF A LION.

CA, the canine teeth, strong and sharp for killing; in front of them (hidden on the lower jaw in the drawing) are the small incisors which are not of much importance. In this respect a carnivore may be contrasted with a grazing animal like a horse, where the incisors are very important for cutting the grass, and the canines are unimportant. The back teeth of the horse have flat upper surfaces suited for crushing and grinding the food ; those of the cat-tribe and dog-tribe among carnivores are adapted for cutting, like compressed blades. There is a specially strong and sharp back tooth (*S*), the sectorial or carnassial, which is in this case the third premolar above and the single molar below.

The lower jaw or mandible (*MN*) works in a deep glenoid fossa (*G*), and has only an up-and-down movement. It is prevented from slipping backwards by a curved post-glenoid process. This kind of articulation should be contrasted with that in a sheep or in a rabbit. To the mandible and in great part to its ascending process (*A*) powerful muscles are attached, which fill up the large temporal fossa between the squamosal (*SQ*) and its zygomatic process (*Z*). The semicircular zygomatic arch, made of the jugal (*J*) in front and the forward extension (*Z*) of the squamosal behind, protrudes greatly, and this is associated with the great mass of the jaw muscles which lie within it. It should be contrasted with the non-protruding zygomatic arch of the horse, where, moreover, a bridge of bone runs from the jugal (*J*) to the frontal (*FR*), bounding the orbit (*O*) behind. In carnivores "the orbit is confluent with the temporal fossa."

At the back of the skull a strong crest or ridge (*OR*), the occipital crest, extends transversely and serves for the insertion of muscles from the neck and the jaw. This may be thought of in connection with the carnivore's habit of dragging its prey along the ground or lifting its young one in its mouth. The crest gives the muscles stronger grip. At right angles to the occipital crest runs the sagittal crest (*CR*) along the mid-dorsal line. It serves for the insertion of muscles from the jaw.

CO is one of the occipital condyles, formed by the ex-occipital bones. By means of the condyles the skull works in two cavities in the first vertebra—the atlas. In front of the condyle there is in cat-like and dog-like (not in bear-like) carnivores, a strong tympanic bulla (*TB*) protecting the drum of the ear. *E* indicates the ear-hole, *PA*, the parietal ; *FR*, the frontal ; *N*, the nasal ; *PMX*, the premaxilla ; *MX*, the maxilla.

ably suited to the function. Every animal is a bundle of adaptations, which have been wrought out through ages and have often attained a high degree of perfection. Disharmonies are sometimes to be detected, especially when the organism is changing its habitat or habits, but they are few and far between. When we consider organs such as the eye, the heart, the kidneys, the placenta binding mother and young together in their intimate ante-natal symbiosis, we discover a multitude of subtle adaptations; and "the narrowest hinge in my hand puts to scorn all machinery"—for the perfection of mammalian joints is extraordinary. When the modern zoologist speaks of the adaptation of an organ he means not only that it is fit, effective, and well-adjusted, but that it is a product of a long process of evolution—the theoretical interpretation of which is still a very difficult problem. Some well-shaped structures, like the heart, are for the most part concerned with the internal economy of the body; others, like limbs, are mainly significant in relation to the environment. But there is no hard and-fast line here, for the ptarmigan's heart is specially adapted to high altitudes and the antelope's to the necessity of rapid escape on the plains. Some adaptations are mainly structural, as we see in the strong arch of a tortoise's carapace, and others mainly functional, as in the arrangements for regulating the temperature of the blood in birds and mammals; but the two aspects are inseparable. Some of the most exquisite adaptations are those that secure the harmonious co-operation of different parts of the body, as when the mother-mammal is prepared for her offspring before its development begins, during the ante-natal life, and after it is born.

From amid innumerable adaptations[1] we select one other instance, that of an African egg-eating snake, *Dasypeltis scabra*, a weak-bodied creature less than a yard in length, which is able to swallow birds' eggs three times the diameter of the thickest part of the body. The jaws are almost toothless, but a few posterior teeth are present which serve to grip the egg. There is the usual

[1] See the author's *Wonder of Life*, p. 523 (Melrose: London, 1914).

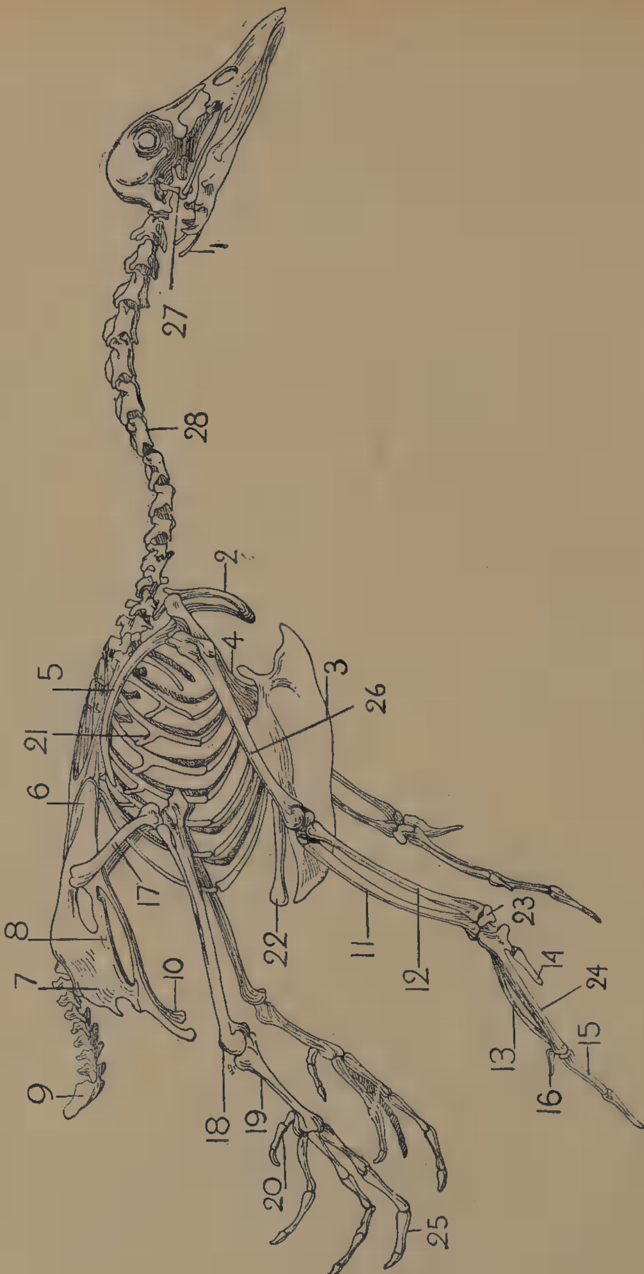

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Fig. 59.—The Skeleton of a Duck in a Flying Position.

Among the many adaptations the following may be noted.

(I) The skeleton is lightly built, many of the bones are hollow girders—light for their size. In many bones of many birds the marrow disappears very early and air-sacs continuous with the lungs pass into the bones. The air-sac system effects economy in the respiratory function and by internal perspiration helps to regulate the body temperature. Underneath the dense cortex of the bones there is often a spongy texture.

(II) At various parts of the skeleton fusion of bones occurs. This is very marked in the skull, and may make it a better pecking instrument. It is characteristic of the dorsal or thoracic vertebræ (5), thus forming a firm fulcrum against which the wings can work. It is very marked in the sacral region, where the true sacrals form along with one or two thoracic, all the lumbars, and half of the caudals a composite syn-sacrum, to which the ilia (6 to 7) are firmly fused. The significance of this is that as the bird walks as a biped, with much of its body in front of a perpendicular dropped from the acetabulum (where the femur or thigh-bone, 17, works on the hip-girdle), there is need for the hip-girdle having a long and strong grip of the backbone. The figure 8 is on the ischium, and 10 on the pubis or post-pubis. After a number of free caudal vertebræ comes the ploughshare bone or pygostyle (9), a terminal fusion which affords a support for the tail-feathers or rectrices. There is a remarkable fusion in the hand, where half of the wrist-bones (carpals) and all the (three) palm-bones (metacarpals) are fused in one bone, the carpo-metacarpus (13 and 24), to which and to the two fingers (15 and 16) the long primary feathers of the wing are attached. It is obviously adaptive that this region should be stiff. A small tuft, the ala spuria, is carried by the thumb (14). The secondary feathers are borne by the ulna (11), which does not move much on its narrower companion bone, the radius (12). Two carpal bones (radiale and ulnare) remain free (23). The humerus is marked 26. There is also a curious fusion of half of the ankle (tarsal) bones. The proximal ones fuse on to the lower end of the tibia, forming the tibio-tarsus (18). The distal ones fuse on to three fused metatarsals, forming the tarso-metatarsus (19). If there be four toes, the first (20) is turned backwards and has a separate metatarsal. The second last joint or phalanx of the fourth toe is marked 25.

(III) As the bird has surrendered its arm to making a wing, the skull has to serve as a hand. Hence the exaggeration of the premaxillæ to form a beak. Adaptive also is the large number (sometimes over a score) of cervical vertebræ (28), which have great freedom of movement. In mammals, with four exceptions, which do not include whale or giraffe, there are but seven cervical vertebræ. The bird's neck has to let the mouth reach the ground, to reach the preen gland at the pygostyle (9), to catch flying insects, and so on. A power of swallowing large hard objects is allowed by the articulation of the lower jaw with the mobile quadrate (27).

(IV) The powerful muscles of flight are chiefly attached to the keel or carina (3) of the breast-bone or sternum. A backward extension of the sternum is marked 22. It will be seen that the breast-bone extends far back, forming a floor to a great part of the abdominal cavity, which is important in a flying creature. The breast-bone is elastically linked to the back-bone by the ribs, which are linked to one another by uncinate processes (21). The sabre-like scapula is marked 5. The merrythought (clavicles and interclavicles) is marked 2. The strong coracoids (4) abutting against the sternum resist the inward crushing action of the down-stroke.

alternate gripping and muscular engulfing, and the intact egg slips into the gullet. It is then met by the sharp points of the inferior spines of a number of the vertebræ, which project into the gullet, and cut the egg-shells. It is said that they are actually tipped with enamel. The result of the structural adaptation is that none of the precious egg is wasted. Mr. Ditmars, the Curator of Reptiles at the Zoological Park in New York, who has a wide experience of living snakes, says that the empty egg-shells are always returned, and that this habit is quite unique.

The student is strongly advised to make a practical study of some structures, such as a sheep's heart, a bullock's eye, a dog's skull, a bird's skeleton, the appendages of a crayfish, the lantern of a sea-urchin, in order to become convinced of the intricacy and finish of adaptations. We have taken the bird's skeleton as an illustration (Fig. 59).

CHAPTER XII

BACKBONELESS ANIMALS

1. Protozoa—2. Sponges—3. Stinging-animals or Cœlentera—4. "Worms"—5. Echinoderms—6. Arthropods—7. Molluscs—8. Other Types

1. **Protozoa.**—It is likely that the first breath of life was in the water, for there most of the simplest animals and plants have their haunts. We call them simple, but there was much truth in Ehrenberg's view, who described some of them in 1838 as "perfect organisms." He was wrong in thinking he saw stomach, heart, and similar organs in them, but right in recognising that they often have a very intricate structure.

There is a widespread erroneous idea that these animalcules are to be found swarming in any drop of water. The clear water of daily use will generally disappoint, or rather please us by showing little trace of living things. But take a test-tube of water from a stagnant pool, hold it between your eyes and the light, and it is likely that you will see many forms of life. Simple plants and simple animals are there, the former represented by threads, ovals, and spheres in green, the latter by more mobile almost colourless specks or whitish motes which dance in the water. But besides these there are jerky swimmers whose appearance almost suggests their popular name of "water-fleas," and wriggling "worms," thinner than thread and lither than eels: both of these may be very small, but closer examination shows that they have parts and organs, that they are many-celled not single-celled animals.

Vary the observations by taking water in which hay

stems or other parts of dusty dead plants have been steeped for a few days, and even with the unaided eye you will see a thick crowd of the mobile whitish motes which, from their frequent occurrence in such infusions, are usually called Infusorians. Or if a piece of flesh be allowed to rot in an open vessel of water, the fluid becomes cloudy and a thin flaky scum gathers on the surface. If a drop of this turbid liquid be examined with a high power of the microscope, you will see small colourless rods and spheres, quivering together or rapidly moving in almost incalculable numbers. These, though without green colour, are the minutest forms of plant life; they are Bacteria or Bacilli, the practically omnipresent microbes, some of which, as disease germs, thin our human population, while others, as cleansers, help to keep the earth habitable.

Three great types of unicellular animals or Protozoa have been recognised in almost every classification.

(*a*) The Infusorians, so abundant in stagnant water, have a common character of activity expressed in the possession of actively mobile lashes of living matter known as cilia or flagella. Thus the slipper-animalcule (*Paramecium*) is covered with rows of lashing cilia, while smaller, equally common forms, generally known as Monads, are borne along by the undulatory movement of one or two long whips or flagella. The bell-animalcules (*Vorticella*) which live in crowds,—a white fringe on the water weeds,—are generally fixed by stalks, but are crowned with active cilia at the upper end of the somewhat urn-shaped cell.

(*b*) In marked contrast to these are the parasitic Gregarines, or Sporozoa, which infest many animals, and cause many diseases, such as the pébrine of silkworms and the malaria of man. They tend to be very sluggish, and they multiply chiefly by forming within the parent cell numerous minute units or spores.

(*c*) Between these two extremes of activity and passivity there is a third type well represented by the much-talked-of *Amœba* which glides about on the mud of the pond, by the sun-animalcules (*Actinosphœrium*) which float in the

clear water of brooks, by the limy-shelled, chalk-forming Foraminifera which move slowly on seaweeds or at the bottom of shallow water, or in some cases float at the

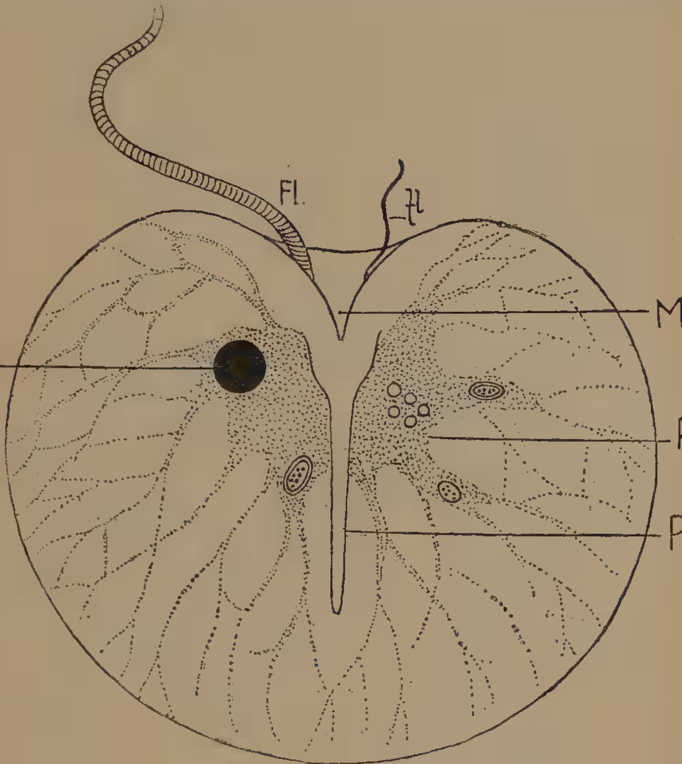


FIG. 60.—A DIAGRAM SHOWING THE STRUCTURE OF *Noctiluca miliaris*, THE COMMONEST CAUSE OF "PHOSPHORESCENCE" IN THE SEA.

It is a flagellate Infusorian, one of the Cystoflagellata, and is enormous for a flagellate, being about the size of a small pinhead ($\frac{1}{25}$ inch or so in diameter). It is rather like a melon in shape.

It drives itself through the water by means of a strong, cross-striated flagellum (*FL*). There is a smaller flagellum (*fl*) that wafts food into the mouth (*M*). The oval depression is continued inwards as a furrow with a rod-like ridge (*R*). The protoplasm (*P*) is dense in the centre around the nucleus (*N*), but very much vacuolated towards the periphery, where it forms a continuous layer beneath the cuticle. The meshes of the protoplasmic network are filled with liquid. Some captured organisms are shown in the central protoplasm, and it is there that the luminosity is most condensed.

surface of the sea, and by the flinty-shelled Radiolarians which live in the open ocean. In all these the living

matter spreads out in thick or thin, stiff or plastic, free or interlacing processes, which often admit of a slow gliding motion, and are still more useful in surrounding minute food particles. To these root-like processes, which are capable of very considerable, often almost constant, change, these Protozoa owe their general name of Rhizopods. In contrast to the two preceding types which have definite boundaries or "skins," the Rhizopods are naked, and their living matter may overflow at any point.

FIG. 61.—A FORAMINIFER (*Polystomella strigillata*) WITH INTERLACING PROCESSES OF THE LIVING MATTER FLOWING OUT ON ALL SIDES. MAGNIFIED FIFTEEN TIMES.

(From Chambers's *Encyclop.*; after Max Schultze.)

As the Infusorians are for the most part provided with cilia from which flagella differ only in detail, we may speak of the type as ciliated; the self-contained Gregarines, often wrapped up within a sheath, we may call predominantly encysted; while those forms which are intermediate between these two extremes, and exhibit outflowing processes of living matter, are called amœboid in reference to their most familiar type, the common Amœba.

But though the members of each class are characterised by the predominance of one of the three phases of cell-life, they sometimes pass from one phase to another. Thus the ciliated or the amœboid units may become encysted.

As the three phases represent the three physiological possibilities of cell-life, it is natural to find that the very

simplest Protozoa, such as *Protomyxa*, exhibit a cycle of amœboid, encysted, and flagellate phases, not having taken a decisive step along any one of the three great paths. Moreover, the cells of higher animals may be

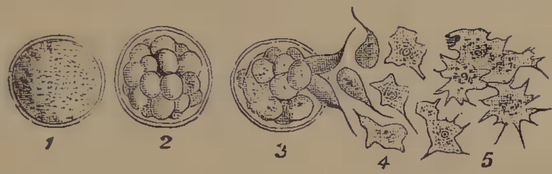


FIG. 62.—PROTOMYXA.

1, Encysted; 2, dividing into many units; 3, these escaping as flagellate cells; 4, sinking into an amœboid phase; 5, fusing into a plasmodium. (From Chambers's *Encyclop.*; after Haeckel.)

classified in the same way. The ciliated cells of the windpipe or the mobile spermatozoa correspond to Infusorians; mature ova, fat-cells, degenerate muscle-cells, correspond to Gregarines; white blood-corpuscles and many young ova are amœboid.

Relation to the Earth.—The floor of the sea for a variable number of miles (not exceeding 300) from the shore is covered with a heterogeneous deposit, washed in great part from the nearest continent. In this deposit shells of Foraminifera usually occur, but they become more numerous farther from the land, where the floor of the sea is often covered with a whitish "ooze," consisting in the main of Foraminifera which in dying have sunk from the surface to the bottom. They are forming the chalk of a possible future, just as many chalk-cliffs and pure limestones represent the ooze of a distant past. In other regions Radiolarians (flinty Rhizopods) or Diatoms (small plants) or Pteropods (minute molluscs) are very abundant. As the Foraminifers have made much of the chalk, so Radiolarians have formed less important siliceous deposits, such as the Barbados Earth, from which Ehrenberg described no fewer than 278 species. At marine depths greater than 2,500 fathoms the Globigerina or other Foraminifer shells are no longer present, not because there are none at the surface, but apparently because

the shells are dissolved before they reach such depths. Here the floor is covered with a very fine reddish or brownish deposit, often called "red-clay," a very heterogeneous mixture of meteoric and volcanic dust and of residues of surface-animals. Along with this, in some of the very deepest parts, *e.g.* of the Central Pacific, there are accumulations of Radiolarian shells, which do not readily dissolve.[1]

Protozoa have many inter-relations with other forms of life. Thus many devour other minute organisms, as well as organic débris. Others again, such as Radiolarians, live in partnership (*symbiosis*) with unicellular Algæ. Many form the fundamental food of small animals of higher degree, such as Copepod Crustaceans. They form an important part of the "stock" of the sea-soup on which many surface animals depend. Moreover, among them there are many parasites both on vegetable and animal hosts. Protozoology has come to be a very important sub-science, comparable to Bacteriology, for some of the deadliest diseases are due to Protozoa. Thus certain disorders of the human alimentary canal and liver are due to species of Amœba, the organism (*Plasmodium* or *Laverania*) that causes malaria is a Sporozoon, and the terrible tropical scourge known as sleeping sickness is caused by an Infusorian (*Trypanosoma*) which is transferred from the blood of some wild animal into man by the bite of the tse-tse fly.

2. **Sponges.**—The first animals to be successful in forming a body were the sponges. They have no organs in the strict sense, but they show the beginnings of muscular, connective, and some other tissues, *i.e.* combinations of similar cells performing similar functions.

Adult sponges are sedentary, and plant-like in their growth. With the exception of the freshwater Spongillidæ they live in the sea fixed to the rocks, to seaweeds and to animals, or to the muddy bottom at slight or at great depths. They feed on microscopic organisms and particles, borne in with currents of water which continu-

[1] For details, see conveniently H. H. Mill's *Realm of Nature* (Lond.), revised edition.

ally flow through the sponge. The sponge is a Venice-like city of cells, penetrated by canals, in which incoming and outflowing currents are kept up by the lashing activity of internal flagellate cells. These flagellate cells, on which the whole life of the sponge depends, line the canal-system, but are especially developed in little clusters or flagellate chambers. The currents are drawn in through very small pores all over the surface; they usually flow out through much larger crater-like openings.

Sponges feed easily and well, and many of them grow out in buds and

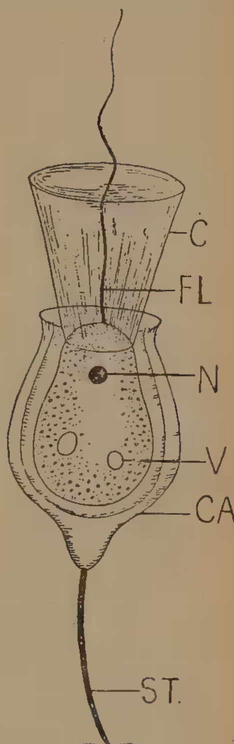


Fig. 63.—An Enormously Enlarged Representation of a Flagellate Infusorian, one of the Choanoflagellata, often called a Monad.
(After Saville Kent.)

The animal is fixed to some object by a stalk (*ST*). It is surrounded by a cuticular cup (*CA*). The living matter is extended into a beautiful delicate collar (*C*), in the middle of which there works a vibratile flagellum (*FL*).

In the cell-substance or cytoplasm a nucleus (*N*) is shown, and there are granules and vacuoles (*V*).

This kind of collared flagellate cells is found only in Choanoflagellata among Infusorians and in the interior of sponges. This suggests that sponges may have been evolved from colonies of Choanoflagellates. The collared cells of sponges are called choanocytes, and it is their activity chiefly that keeps the water-currents a-going.

branches. A form which was at first a simple cup may grow into a broad disc or into a tree-like system. And as trees are blown out of shape by the wind, so sponges are moulded by the currents which play around them, as well as by the nature of the objects on which they are fixed. Like many other passive organisms, sponges almost always have a well-developed skeleton, made of flinty needles and threads, of spicules of lime, or of fibres of flexible spongin familiar to us in the bath sponge. While sponges do not rise high in organic rank, they have many internal complications and much beauty.

16

Sponges may be classified according to their skeleton, as calcareous, flinty, flinty and horny, and purely horny. The calcareous forms with needles of lime have a world-wide distribution in the sea, but not in the great deeps. They often retain a cup-like form, but vary greatly in the complexity of their canals. The purse-sponge (*Grantia compressa*) is common on British shores. The siliceous sponges are more numerous, diverse, and complicated, and the flinty needles or threads are often combined with a fibrous spongin skeleton. Venus' Flower-basket (*Euplectella*) has a glassy skeleton of great beauty, Mermaids' Gloves (*Chalina oculata*) with needles of flint and horny fibres is often thrown up on the beach, the Crumb-of-Bread Sponge (*Halichondria panicea*) spreads over the low-tide rocks. Some have strange habits, witness *Cliona* which bores holes in oyster shells, or *Suberites domuncula* which clothes the outside of a whelk shell tenanted by a hermit-crab. The purely "horny" sponges which have a fibrous skeleton of "spongin" but no proper spicules are well represented by the bath-sponges (*Euspongia*) which thrive well off Mediterranean coasts, where they are farmed and even bedded out.

Sponges are ancient but unprogressive animals. Their sedentary habits, from which only the embryos for a short time escape, have been fatal to further progress. They show tissues as it were in the making. They are living thickets in which many small animals play hide-and-seek. Burrowing worms often do them much harm, but from many enemies they are protected by their skeletons and by their unpalatability.

3. **Stinging-Animals or Cœlentera.**—It is difficult to find a convenient name for the jelly-fish and zoophytes, sea-anemones and corals, and many other beautiful animals which are called Cœlenterates; but the fact that almost all have poisonous stinging lassoes in some of their skin-cells suggests that which we now use.

Representatives of the chief divisions may be sometimes found in a pool by the shore. Ruddy sea-anemones, which some call sea-roses, nestle in the nooks of the rocks; floating in the pool and throbbing gently is a jellyfish

left by the tide ; fringing the rocks are various zoophytes, or, if we twist the name backwards, plant-like animals ; besides these, and hardly visible in the clear water, are minute translucent bells some of which are the liberated reproductive individuals of a zoophyte colony ; and there are yet other exquisitely delicate, slightly iridescent globes—the Ctenophores, which have been brought in from the open sea, and move by rows of comb-like structures formed of fused cilia. But we must search an inland pool to find one of the very simplest members of this class—the freshwater *Hydra* which hangs from the floating duckweed and other plants.

This *Hydra* is a tubular animal often about a quarter of an inch in length. One end of the tube is fixed, the other bears the mouth surrounded by a crown of mobile tentacles. It is so simple that cut-off fragments, if not too minute, may grow into complete animals ; when well fed, the *Hydra* buds out little polyps like itself, and these are eventually set free.

If we suppose the budding of *Hydra* continued a hundredfold, till a branched colony of connected individuals is formed, we have an idea of a hydroid or zoophyte colony. For a zoophyte is a colony of many hydra-like polyps, which are supported by a continuous outer framework and share a common life. Numerous as may be the " persons " on a branched hydroid, all have arisen from one more or less Hydra-like individual.

Sometimes, however, there is a marked division of labour in such a colony, as in *Hydractinia* which has nutritive, reproductive, sensitive, and perhaps also protective " persons,"—three or four castes into which the colony is divided. (See fig. 21.) The difference between nutritive and reproductive members is often well marked, and this has a special interest in the case of many zoophytes. For many of these, especially among those known as Tubularians and Campanularians, have reproductive individuals which are set adrift as small swimming-bells or medusoids, somewhat like miniature jellyfish. A fixed plant-like, asexual hydroid colony buds off free-swimming, sexual medusoids, from the fertilised eggs of

which embryos develop which grow into hydroids. This is known as alternation of generations, and is a remarkable illustration of activity and passivity combined in one life-cycle. It may be defined as the alternate occurrence in one life-history of two (or more) different forms differently produced. (See fig. 100.)

But all the miniature jellyfish in the sea are not the liberated reproductive buds of hydroid colonies. Some which are in structure exceedingly like the liberated medusoids never have any connection with a hydroid. Their embryos grow into medusoids like the parents. Quite distinct from these medusoids, though sometimes superficially like them, are the true jellyfishes which are frequently stranded in great numbers on the beach. These medusæ belong to a different series, and some of their features link them rather to the sea-anemones than to the hydroids.

The sea-anemones and the corals are tubular animals whose mouths are encircled by tentacles, but they are more complicated internally than the polyps of the hydroid type. For the latter are simple tubes, while the sea-anemones and their relatives have a turned-in gullet, and the inside tube thus formed is connected with the outer wall of the body by many radiating partitions, some idea of which can be gained by looking at the skeletons or shells of many corals. Related to the sea-anemones but different in some details, are many colonies, of which Dead-men's-fingers (*Alcyonium digitatum*), the Precious Coral (*Corallium rubrum*), the Organ-pipe Coral (*Tubipora musica*), the sea-fans or Gorgonians, and the sea-pens or Pennatulids are well-known types. The term "coral," it may be explained, has a wide significance; it is applied to any cœlenterate with a strongly developed hard skeleton.

Besides the types of Cœlentera which we have mentioned there are others, especially certain corals belonging to the hydroid series and known as Millepores, also the Portuguese Man-of-war and its relatives (Siphonophora), which are colonies of more or less medusoid individuals with much division of labour, the curious Black Corals

Fig. 64.—A True Jellyfish or Medusa, technically one of the Acraspeda or Scyphomedusæ.

Four frilled lips hang down from the mouth, numerous tentacles arise from the margin of the umbrella, and it may be noted that tentacles of some sort are very characteristic of the Cœlentera.

In the centre of the disc or umbrella there is a stomach from which canals radiate out to the circumference, opening into an annular circumference canal. A great part of the disc consists of a watery gelatinous stratum—the mesoglœa. Numerous muscle-cells arranged on the under-surface of the disc serve to alter the curvature of the disc and thus to move the Medusa.

or Antipatharians which are distantly related to sea-anemones. The beautiful open-sea Ctenophores or Comb-bearers, such as *Beroë* and *Pleurobrachia*, represent the climax of activity among Cœlenterates. They move by combs of fused cilia and are in many ways so divergent, *e.g.* in having the stinging cells in almost all cases replaced by adhesive cells, that many zoologists would place them quite outside the series of Cœlentera.

FIG. 65.—THE ALTERNATION OF GENERATIONS IN THE COMMON JELLY-FISH *Aurelia*.

1, The free-swimming embryo ; 2, the embryo settled down ; 3, 4, 5, 6, the developing asexual stages, or hydra-tubæ ; 7, 8, the formation of a pile of individuals by transverse budding ; 9, the liberation of these individuals ; 10, 11, their progress towards the free-swimming sexual medusa form.

(From the *Evolution of Sex* ; after Haeckel.)

Besides Hydra there are few other freshwater Cœlentera, such as the hydroid *Cordylophora* which occurs in brackish water and in canals, a strange form *Polypodium* which is parasitic in its youth on the eggs of the Russian sturgeon, and a few remarkable freshwater jellyfishes, *e.g. Limno-*

codium from Lake Tanganyika and elsewhere. Apart from these and a few other exceptional forms, Cœlentera live in the sea. Hydroids grow on rocks and shells and on the backs of crabs and other animals which they mask ;

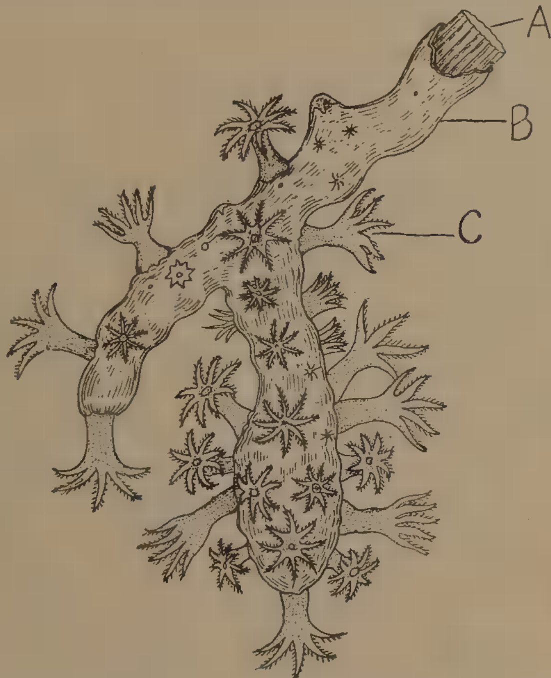


FIG. 66.—A PORTION OF THE PRECIOUS CORAL OR RED CORAL OF COMMERCE, *Corallium rubrum*, A COLONY OF ALCYONARIAN POLYPS.
(After Lacaze-Duthiers.)

The polyps (*C*) or members of the colony are white. Each has eight feathery tentacles surrounding the mouth; the general cavity (cœlenteron) between the gullet and the body wall is divided into eight compartments by eight upright partitions or mesenteries.

The polyps are connected by red flesh (*B*) in which are imbedded canals connecting the cavities of adjacent polyps with one another. The redness is due to innumerable tuberculated spicules (of carbonate of lime) of a red colour.

In the centre there is the red stony axis, which is used in making ornaments. It is due to a coalescence of innumerable spicules, but how the fusion is effected we do not know.

sea-anemones live on the shore-rocks—but not a few are found at considerable depths ; the medusoids and jellyfishes frequent the opener sea, where Siphonophores and Ctenophores bear them company.

It is instructive to contrast the various kinds of corals. Dead-men's-fingers with numerous jagged spicules of lime in its flesh is just beginning to be coralline. Similar spicules have been fused together in external tubes in the organ-pipe coral. In the red coral of commerce the calcareous material forms an axis around which the individuals are clustered. Very different are the reef-building corals, where the cup in which each individual lived is more or less well marked according as it has remained distinct or fused with its neighbours, and where an image of the fleshy partitions of the sea-anemone-like animal is seen in the radiating septa of lime.

We begin the series of many-celled animals with Sponges and Cœlenterates, partly because they are on the whole simplest, but more precisely because their types of structure are least removed from that two-layered sac-like embryo or gastrula which recurs in the life-history of most animals, and which we have much warrant for regarding as a hint of what the first successful many-celled animals were like. The Sponges and Cœlenterates differ from the higher animals: (1) In retaining the symmetry of this gastrula, in being, like it, radially symmetrical, and in so growing that the axis extending from the mouth to the opposite pole corresponds to the long axis of the embryo; (2) in being two-layered animals, for between the outer skin and the lining of the internal food-cavity there is only a more or less indefinite jelly instead of a definite stratum of cells; (3) in having only one internal cavity, instead of having, like most other animals, a body-cavity within which a distinct food-cavity lies.

Regarding the layers of the body, we may notice here that the outer layer of cells is called the ectoderm, the inner layer the endoderm. In Ctenophores, which we have noted as divergent, a third fundamental layer—the mesoderm—takes the place of the rather indefinite mesoglœa or middle jelly of other Cœlentera. Though one would not perhaps suspect it, there are some striking suggestions in Ctenophores of relationship with the simplest flat-worms—the Turbellarians.

4. "**Worms.**"—This title is one of convenience, without strict justification. For there is no class of "worms," but an assemblage of classes which have little in common. "Worm" is little more than a name for a shape, most of the animals so called differing from anemones and jellyfish in having head, tail, and sides. The simplest worms were apparently the first many-celled animals to move persistently head foremost, thus acquiring distinct bilateral symmetry, and a definite nervous centre or brain in that region which had most experience—the head. The mesoderm, or middle layer of cells, which is incipient in Ctenophores, increases in importance. In our survey we are helped by the fact that many worms consist of a series of rings or segments, while others are all one piece or unsegmented. It is generally true that the latter are in structure simpler and more primitive than the former. In the ringed worms or Annelids a body-cavity or cœlom appears—a mesoderm-lined cavity between the gut and the body-wall. Among "worms," therefore, the series of Cœlomate, as contrasted with Cœlenterate animals, makes its beginning.

1st Set of Worms. **Plathelminthes** or **Flat Worms.**—Class: Turbellaria or Planarians.—These are small worms, living in the sea or in fresh water, or occasionally in damp earth, covered externally with cilia, very simple in structure, usually feeding on minute animals. The genus *Planaria*, common in fresh water; green species of *Vortex* and *Convoluta*, which owe their colour to minute algæ living in intimate partnership or symbiosis with them; *Microstoma*, which by budding forms temporary chains of eight or sixteen individuals as if suggesting how a ringed worm might arise; *Gunda*, with a hint of internal segmentation; and two parasitic genera—*Graffilla* and *Anoplodium*—may be mentioned as representatives of this class. Specimens may be obtained by collecting the waterweeds from a pond or seaweeds from a shore-pool, and the simplicity of some may be demonstrated by observing that when they are cut in two each half lives and grows.

Class: Trematoda or Flukes.—These are parasitic

"worms," living outside or inside other animals, often flat or leaf-like in form, provided with adhesive suckers. Those which live as ectoparasites, *e.g.* on the skin of fishes, have usually a simple history; while those which

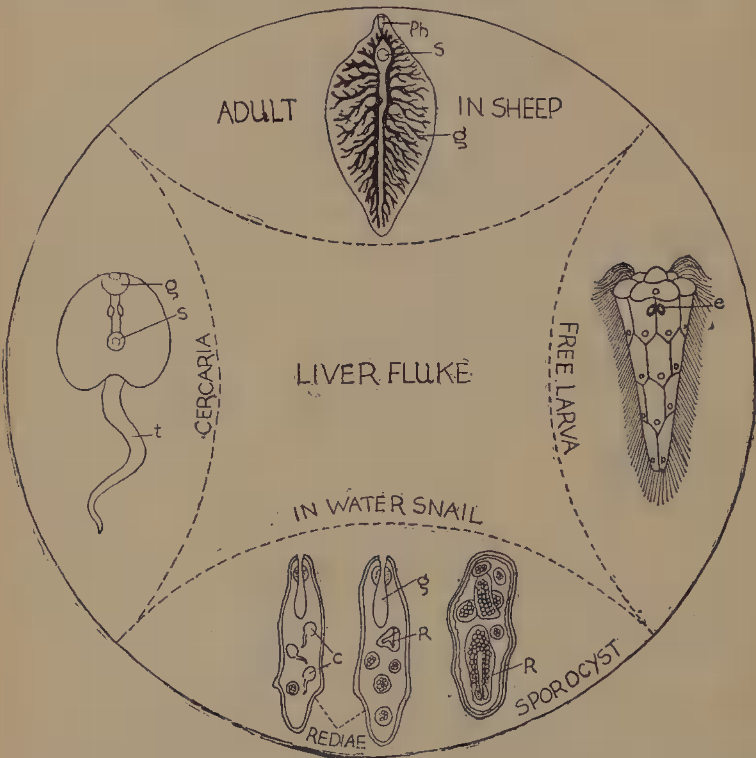


FIG. 67.—DIAGRAMMATIC REPRESENTATION OF THE LIFE-HISTORY OF THE LIVER-FLUKE (*Distomum hepaticum*). IT IS SHOWN IN FOUR CHAPTERS, TWO FREE AND TWO PARASITIC.

The adult fluke is shown at the top, about natural size. The anterior terminal mouth leads into a suctorial pharynx (*Ph*), and this into the very intricately branched food-canal (*g*) which has no anus. Behind the mouth on the ventral surface is a muscular adhesive sucker (*S*).

The next chapter to the right shows the free-swimming microscopic larva or miracidium. It has only a few cells, the nuclei of which are shown. It is covered with cilia and has two eye-spots (*e*).

The third chapter is in the water-snail (*Limnæa truncatula*). The miracidium becomes a sporocyst, inside that rediæ (*R*) are formed. Inside the redia, which has a gut (*g*), more rediæ develop, and there are in summer two generations of rediæ. In the last set cercariæ (*C*) are developed.

The fourth chapter shows the cercaria, with a locomotor tail (*t*), an attaching sucker (*S*), and the beginning of other organs. It leaves the snail and the water, and encysts on grass—a very minute spot. If it be swallowed by a sheep, it develops into a fluke.

are internal boarders have an intricate life-cycle, requiring to pass from one host to another of a different kind if their development is to be fulfilled. Thus the liver-fluke (*Distomum hepaticum*), which causes the disease of liver-rot in sheep, and has sometimes destroyed a million in one year in Britain alone, has an eventful history. From the bile-ducts of the sheep the embryos pass by the food-canal to the exterior. If they reach a pool of water they develop for 2–3 weeks, quit their thick egg-shells, and become for a few hours free-swimming. The active larvæ, known as miracidia, knock against many things, to which they pay no heed, but when they come in contact with a small water-snail (*Limnæa truncatula*) they fasten to it, bore their way in, and, losing their locomotor cilia, encyst themselves. The encysted forms, known as sporocysts, grow and multiply in a remarkable asexual way. Cells within the body of the sporocyst develop into a second generation quite different in form. These are known as rediæ, and each sporocyst forms 5–8 of them. Within the rediæ more rediæ (8–12) are produced, and the last generation of rediæ produce (12–20) minute tailed flukes or cercariæ. In winter there may be but one generation of rediæ. The cercariæ leave the moribund snail, leave the water, climb on to blades of grass near the pool, lose their tail, and encyst. They look like little white spots. If they happen to be eaten by a sheep, they pass into the liver and develop in about six weeks into fully-formed flukes. Others have not less eventful life cycles, but that of the liver-fluke is most thoroughly known. When we dissect a frog we often find *Polystomum integerrimum* in the lungs or bladder; it begins as a parasite of the tadpole, and takes two or three years to become mature in the frog. Quaint are the little forms known as *Diporpa* which fasten on the gills of minnows, and unite in pairs for life, forming double animals (*Diplozoon*); and hardly less strange is *Gyrodactylus*, another parasite on freshwater fishes, for three generations are often found together, one within the other. The most formidable fluke-parasite of man is *Bilharzia*, common in Africa, which, like the Liver-fluke,

spends part of its life inside a water-snail. The cercariæ pass from the snail (*Planorbis*, *Bulinus*) into the water, and they are able to enter man through minute cuts in the skin of hands and feet.

Class: Cestoda or Tapeworms.—These are all internal parasites, and, with the exception of one (*Archigetes*), which fulfils its life in the little river-worm *Tubifex*, the adults always occur in the food-canal of backboned animals. Like the flukes, they have adhesive suckers, and sometimes hooks as well; unlike flukes and planarians, which have a food-canal, they absorb the juices of their hosts through their skin, and have no mouth or gut. Like the endo-parasitic flukes, the tapeworms have (except *Archigetes*) intricate life-histories. Both Turbellarians and Trematodes are small, rarely more than an inch or so in length, but the tapeworms may measure several feet. In the adult *Tænia solium*, which is sometimes found in the intestine of man, we see a small head like that of a pin; it is fixed by hooks and suckers to the wall of the food-canal; it buds off a long chain of "joints," each of which is complete in itself. As these joints are pushed by continued budding farther and farther from the head, they become larger, and distended with eggs, and even with embryos, for the hermaphrodite tapeworm is able to fertilise its own ova—a very rare thing among animals. The terminal joints of the chain are set free, one or a few at a time, and they pass down the food-canal to the exterior, where they eventually burst. The microscopic embryos which they contain when fully ripe are encased in firm shells. It may be that some of them are eaten by a pig, the shells are dissolved away in the food-canal, small six-hooked larvæ (hexacanths) emerge. These bore their way into the muscles of the pig and lie dormant, increasing in size however, becoming little bladders, and forming a tiny head. They are called bladder-worms, and it was not till about the middle of the nineteenth century that they were recognised as the young stages of the tapeworm. For if the diseased pig be killed and its flesh be eaten half-cooked by man, then each bladder-worm may become an adult sexual tape-

worm. The bladder part is of no importance, but the head fixes itself and buds off a chain. For many others the story is similar ; the bladder-worm of the ox becomes another tapeworm (*Tænia saginata*) in man ; the bladder-worm of the pike or burbot becomes another (*Bothriocephalus latus*) ; the bladder-worm of the rabbit becomes one of the tapeworms of the dog, that of the mouse passes to the cat, and so on. A bladder-worm which forms many heads destroys the brain of sheep, causing "sturdie" or staggers, and has its tapeworm stage (*Tænia cœnurus*) in dog or wolf. Another huge bladder-worm, which has also many heads, and sometimes occurs in man as well as in cattle, sheep, and pigs, etc., has also its tapeworm stage (*Tænia echinococcus*) in the dog. But enough of these vicious cycles.

2nd Set of Worms. **Ribbon Worms** or **Nemerteans.**—Class : Nemertea.—In pleasing contrast to the flukes and tapeworms, the Nemerteans are free-living "worms." They are mostly marine, often brightly coloured, almost always elongated, always covered with cilia. There is a distinct food-canal with a posterior opening, a blood-vascular system for the first time, a well-developed nervous system, a remarkable protrusible "proboscis" lying in a sheath along the back, a pair of enigmatical ciliated pits on the head. The sexes are almost always separate. Almost all Nemerteans are carnivorous, but two or three haunt other animals in a manner which leads one to suspect some parasitism ; thus *Malacobdella* lives within the shells of bivalve molluscs. We find many of them under loose stones by the sea-shore ; one beautiful form, *Lineus marinus*, sometimes measures over twelve feet in length. Some, such as *Cerebratulus*, break very readily into parts, even on slight provocation, and these parts are sometimes able to regrow the whole. We look back to them with peculiar interest for several reasons, one of which is that some of them show, for the first time in the animal kingdom, hæmoglobin,—the blood-pigment which makes the blood of backboned animals red, and is of fundamental importance because of the ease with which it enters into a loose chemical union with oxygen. Nemer-

teans are the first animals to show an open food-canal, and there is a body-cavity in the larvæ at least.

3rd Set of Worms. **Nemathelminthes** or **Round Worms.**—Class: Nematoda or Thread-worms.—The "worms" of this class are cylindrical, like pieces of string or thread. The body is covered by a firm glistening cuticle, which is periodically moulted; the body-wall is muscular; in most a simple food-canal extends from end to end of the body; the sexes are usually separate. Many of the Nematodes live in damp earth and in rottenness; many are, during part of their life at least, parasitic in animals or plants. We have already noticed how long some of them—"paste-eels," "vinegar-eels," etc.—may lie in a dried-up state without dying. The life-histories are often full of vicissitudes; thus the "ear-cockles" worm (*Tylenchus tritici*) passes from the earth into the ears of wheat, and many others make a similar change; the female of *Sphærularia bombi* migrates from damp earth into humble-bees, and there produces young which find their way out; others, *e.g.* some of the thread-worms found in man (*Oxyuris*, *Trichocephalus*), pass from water into their hosts; others are transferred from one host to another, as in the case of the *Trichina* with which pigs are infected by eating rats, and men infected by eating diseased pigs, or the small *Filaria sanguinis hominis*, sometimes found in the blood of man, which passes its youth in a mosquito. Somewhat different from the other Nematodes are those of which the horse-hair worm *Gordius* is a type. They are sometimes found inside animals (water-insects, molluscs, fish, frog, etc.), at other times they appear in great numbers in the pools, being, according to popular superstition, vivified horse-hairs. There is another allied class, Acanthocephala, including a few genera, *e.g.* *Echinorhynchus*, of parasitic habit, the young stages occurring in crustaceans and insects, the adults in vertebrates.

4th Series of Worms. **The Annelids** or **Ringed Worms.**—Class: Chætopoda or Bristle-footed "worms."—In the earthworms (*Lumbricus*, etc.), in the freshwater worms (*Nais*, *Tubifex*, etc.), in the lobworms (*Arenicola pisca-*

torum), and in the sea-worms (*Nereis*, *Aphrodite*, etc.), all of which are ranked as Chætopods, the body is divided into a series of similar rings or segments, and there are always some, and often very many, bristles on the outer surface. The segments are not mere external rings, but divisions of the body often partially partitioned off internally, and there is usually some repetition of internal organs. Thus in each segment there are often two little kidney-tubes or nephridia, while reproductive organs may occur in segment after segment. Moreover, there are often two unjointed appendages or parapodia on each ring. The nervous system consists of a dorsal brain and of a double nerve-cord lying along the ventral surface. The nerve-cord has in each segment a pair of nerve-centres or ganglia, and divides in the head region to form a ring round the gullet which unites with the brain above. The existence of nerve-centres for each segment makes each ring to some extent independent, but the brain rules all. This type of nervous system represents a great step of progress ; it is very different from that of Stinging-animals, which lies diffusely in the skin or forms a ring around the circumference ; different from that of the lower "worms," where the nerve-cords from the brain usually run along the sides of the body ; different from that of molluscs, where the nerve-centres are fewer and tend to be concentrated in the head ; different finally from the central nervous system of backboned animals, for that is wholly dorsal. But the type characteristic of ringed "worms" —a dorsal brain, a ventral chain of ganglia and a ring round the pharynx or gullet connecting the two—is also characteristic of crustaceans, insects, and related forms. It is called the Annulate type of nervous system.

Of bristle-footed "worms," there are two great sets, the earth-worms and the sea-worms. The former, including the common soil-makers and a few giants, such as the Tasmanian *Megascolides*, sometimes about six feet long, have bristles but no parapodia ; sense-organs, feelers, and breathing organs are undeveloped, as one would expect in subterranean animals. The sea-worms, on the other hand, have usually stump-like bristly para-

podia, and eyes and tentacles and gills, but there is much difference between those which swim freely in the sea (*e.g.* *Alciope* and *Tomopteris* and some Nereids) and the lobworms which burrow and make countless castings upon the flat sandy shores, or those which inhabit tubes of lime or sandy particles (e.g. *Serpula*, *Spirorbis*, and *Lanice* or *Terebella conchilega*). The earthworms with compara-

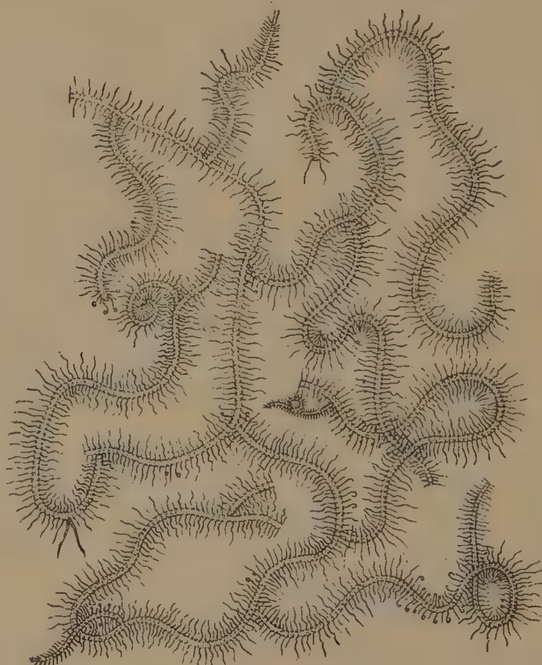


FIG. 68.—A BUDDING MARINE WORM (*Syllis ramosa*). (From *Evolution of Sex*; after M'Intosh's *Challenger* Report.)

tively few bristles (Oligochæta) are hermaphrodite, while almost all the marine worms with many bristles (Polychæta) have separate sexes. Moreover, those of the first series usually lay their eggs in cocoons, within which the embryos develop without any metamorphosis, while the sea-worms, though they sometimes form cocoons, have free-swimming larvæ usually very different from the adults—little barrel-shaped or pear-shaped ciliated creatures known as Trochospheres.

Some of the Chætopods multiply not only sexually, but asexually by dividing into two or by giving off buds from various parts of their body. Strange branching growths, which eventually separate into individuals, are well illustrated by the freshwater *Nais*, and still better by a marine worm, *Syllis ramosa*, which almost forms a network (fig. 68).

Many sea-worms have much beauty, which some of their names, such as *Nereis*, *Aphrodite*, *Alciope*, suggest, and which is said to have induced a specialist to call his seven daughters after them.

Along with the Chætopods, we include some other forms too unfamiliar to find more than mention here, the Myzostomata which form gall-like growths on the feather-stars which they infest, the strange *Bonellia* where the microscopic male lives as a parasite on or within the female, and some very simple forms, e.g. *Polygordius*, which are sometimes called Archi-Annelids.

Class: Hirudinea or Discophora or Leeches.—These are blood-sucking animals, which often cling for a long time to their victims. They live in salt and in fresh water, and sometimes on land. The body is elastic and ringed, but the external markings do not correspond to the internal segments. There are no appendages, but the mouth is suctorial, and there is another adhesive sucker posteriorly. The body-cavity is almost obliterated by a growth of spongy tissue, whereas that of Chætopods is roomy. Leeches are hermaphrodite, and lay their eggs in cocoons, within which the young develop without metamorphosis.

The medicinal leeches (*Hirudo medicinalis*) live in slow streams and marshes, creeping about with their suckers or sometimes swimming lithely, preying upon fishes and amphibians, and both larger and smaller animals. They fix themselves firmly, bite with their three semicircular saw-like tooth-plates, and gorge themselves with blood. When they get an opportunity they make the most of it, filling the many pockets of their food-canal. The blood is kept from coagulating by means of a secretion, and on its store the leech may live for many months.

The horse-leech (*Hæmopis sanguisuga*) is common in

Britain and elsewhere. The voracious *Aulostoma* is rather carnivorous than parasitic. The land-leeches (*e.g. Hæmadipsa ceylonica*), though small and thin, are very troublesome, sucking the blood of man and beast. Among the others are the eight-eyed *Nephelis* of our ponds, the little *Clepsine* which sometimes is found with its young attached to it, the warty marine *Pontobdella* which fastens on rays, *Piscicola* on perch and carp, *Branchellion* with eleven pairs of respiratory leaflets of skin, and the largest leech—the South American *Macrobdella valdiviana*, which is said to attain a length of over two feet.

Possibly related to the Annelid series are two other classes—

Class—Chætognatha, including two genera of small arrow-like marine "worms," *Sagitta* and *Spadella*.

Class—Rotifera, "wheel animalcules," abundant and exquisitely beautiful animals inhabiting fresh and salt water and damp moss. The head-region bears a ciliated structure, whose activity produces the impression of a swiftly rotating wheel. Many of them seem to be entirely parthenogenetic. Some can survive being made as dry as dust.

But there are yet other classes included in this difficult assemblage of "worms"—

Class—Sipunculoidea, "spoon-worms" living in the sea, freely or in tubes, *e.g. Sipunculus*.

Class—Priapulidea, including several marine worms.

Class—Phoronoidea, including *Phoronis* and *Phoronopsis*.

Class—Polyzoa or Bryozoa, with one exception forming colonies by budding, in fresh water or in the sea, *e.g.* the common sea-mats or horn-wracks (*Flustra*).

Class—Brachiopoda or Lamp-shells, a class of marine shelled animals once much richer in members, now decadent. They have a superficial, but only a superficial, resemblance to Molluscs.

We have not catalogued all these classes of "worms"

without a purpose. Our aim has been to suggest that there is a great variety—a mob—of worm-like animals, which zoologists have not yet reduced to order. The "worms" lie as it were in a central pool among backboneless animals, from which have flowed many streams of progressive life. They have affinities with Echinoderms, with Insects, with Molluscs, with Vertebrates.

To practical people the study of "worms" has no little interest. The work of earthworms is pre-eminently important; the sea-worms are often used as bait; the leech was once the physician's constant companion; numerous parasitic worms injure man, his domesticated stock, and the crops of his fields.

5. **Echinoderma.**—In contrast to the "Worms," the series including starfishes, brittle-stars, feather-stars, sea-urchins, and sea-cucumbers, is well defined.

The Echinoderma are often ranked next the stinging animals, mainly because many of the adults have a radiate symmetry, as jellyfishes and sea-anemones have. But radiate symmetry is a superficial character, perhaps originally due to a sedentary habit of life in which all sides of the animal were equally affected. Moreover, the larvæ of Echinoderms are bilaterally symmetrical, that is to say, they are divisible into halves along a median plane. We place Echinoderms after and not before "worms," because the simplest worm-like animals are much nearer the hypothetical gastrula-like ancestor than are any Echinoderms, and also because there is some reason to believe that Echinoderms originated from some worm type or other.

Of Echinoderms there are many classes, five of which are represented nowadays in our seas, namely, starfishes or Asteroids, brittle-stars or Ophiuroids, sea-urchins or Echinoids, sea-cucumbers or Holothuroids, and feather-stars or Crinoids. Among the extinct classes, such as Cystoids and Blastoids, there are some very interesting types which show how the classes that have persisted may have been linked together in the past.

Many starfishes are very carnivorous, but others depend a good deal on the lines of ciliated cells on their

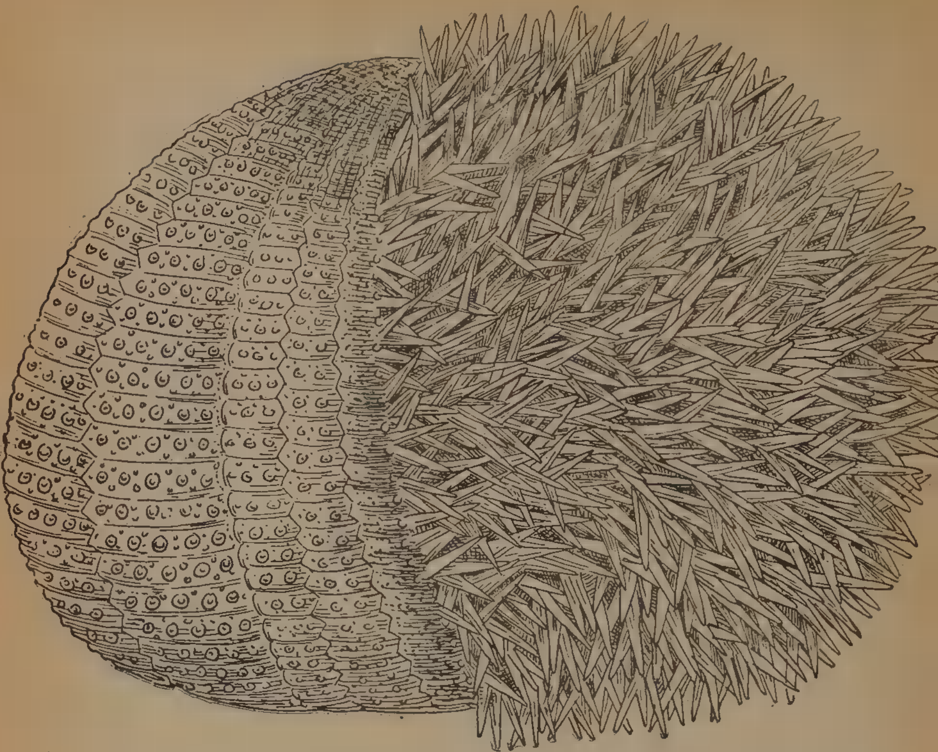


FIG. 69.—THE COMMON SEA-URCHIN, *Echinus esculentus*. THE SPINES HAVE BEEN RUBBED OFF FROM HALF OF THE SHELL OR TEST.

As a preliminary discipline in exactness, a thorough study of the skeletal parts of the sea-urchin is recommended to the student.

It is a mesodermic skeleton, covered during life by a delicate, tissue-paper-like, ciliated ectoderm.

At the lower pole is the mouth, from which project the five teeth of Aristotle's lantern—a remarkable apparatus used in mastication and also in locomotion on a flat surface.

At the upper pole the food-canal ends and around the polar area is a complicated apical disc with five genital plates and five so-called ocular plates. Through a hole in each ocular plate a sensitive tube-foot emerges. Through a hole in each genital plate the germ-cells are shed into the water. But the largest of the genital plates, called the madreporic plate, has a structure like the rose of a watering-can, and serves as the entrance to the water-vascular system which enables the sea-urchin to climb up the side of a shore-pool.

In a line with the ocular plates are five narrow areas, each composed of a double row of plates. These are called ambulacral areas, and along them, through numerous pores, the locomotor suctorial tube-feet of the water-vascular system emerge. There are also spines on these ambulacral areas.

In a line with the genital plates are five broad areas, each composed of a double row of plates, bearing spines only. These are called inter-ambulacral areas.

The spines are of various sizes. They are longitudinally grooved and have a beautiful internal zoned architecture. They are worked by muscles on ball and socket joints. The ball is a prominence on the test; the socket is the base of the spine. Among the ordinary spines are four kinds of small snapping pedicellariæ and also spherical sensory sphæridia.

surface, which sweep particles into the mouth. The common sea-urchins browse on acorn-shells and seaweed; the heart-urchins press sand into their widely open mouths. Some of the Holothurians plunge one feathery tentacle after another (see fig. 70) into the mud and then into their mouth. To a large extent Echinoderms feed on minute living creatures and on organic detritus.

The Echinoderms are sluggish animals, though many brittle-stars are lithe gymnasts, and though the commonest Crinoids (Comatulids, such as the rosy feather-star, *Antedon rosacea*) differ from their stalked relatives and adolescent stages in being to some extent swimmers. Perhaps the sluggishness is expressed in the abundance of lime in the skin and other parts; for, as the name suggests, the Echinoderms are thorny-skinned, being usually protected by calcareous plates and spines. The sea-cucumbers are the most muscular and the least limy, in some indeed almost the only calcareous parts are a few anchors and plates scattered in the skin.

Very important is the development of a peculiar system of canals and suctorial "tube-feet"—the water-vascular system. By means of the tube-feet the starfishes and sea-urchins move, in the others their chief use seems to be in connection with respiration.

Of great interest is the primitive nature of the nervous system, which often remains very superficial, retaining its connection with the skin. But besides that, there is the striking rarity of nerve-centres or ganglia. There is little evidence of them except in some brittle stars. This is particularly interesting, because some Echinoderms exhibit quite a complex behaviour, for instance when a starfish does battle with a sea-urchin. Moreover, the experiments made by Prof. Jennings show very clearly that a starfish is able to profit by experience. It can do this although it has no nerve-ganglia, only rows of nerve-cells. In other words, there may be considerable complexity of behaviour though the structure of the nervous system remains very simple. This confirms what was noted in regard to organic purposiveness in the Protozoa.

Another characteristic of the Echinoderms is the strangeness of the larval forms. For not only are the larvæ very different from the parents, and very remarkable in form, but they do not grow directly into the adult. The development is "indirect," the larva does not become the adult; the foundations of the adult are laid anew within the body of the larva, which is absorbed or partly rejected.

In a relatively small number of cases, among starfishes, sea-urchins, and sea-cucumbers, there is some measure of parental care, the young ones remaining for a prolonged period externally associated with the mother. In these cases the usual free-swimming larval stages are suppressed and there is often at least some obvious reason for this. Thus the parental association is seen in a number of Arctic and Antarctic forms where the abundance of ice is prejudicial to the success of delicate larval forms.

Not only the starfishes but also the brittle-stars and the feather-stars often surrender their arms when captured, or even when slightly irritated, and a part or a remnant can in favourable conditions regrow the whole. The Holothurian *Synapta* breaks readily into pieces, and others contract themselves so forcibly that the internal organs are extruded.

The relations of Echinoderms to other animals are many. A little fish, *Fierasfer*, goes in and out of Holothurians; the degenerate Myzostomata form galls on the arms of Crinoids; starfishes are deadly enemies of oysters. On the other hand, some sea-snails and fishes prey upon Echinoderms in spite of their grittiness. Except that the unlaid eggs of some sea-urchins are edible, and that some sea-cucumbers are considered delicacies, the Echinoderms hardly come into direct contact with human life.

6. **Arthropods.**—Lobsters, centipedes, insects, spiders, agree with the Annelid "worms" in being built up of a series of rings or segments. Some or all of these segments bear limbs, and these limbs are jointed, as the term Arthropod implies. The skin forms an external

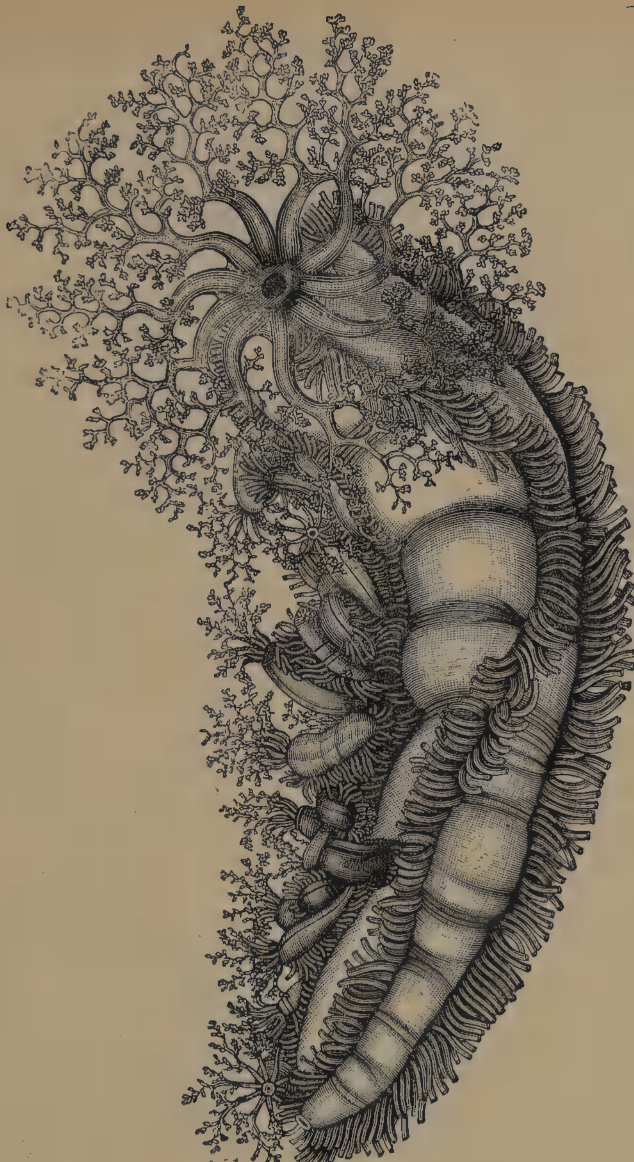


FIG. 70.—A HOLOTHURIAN (*Cucumaria crocea*) WITH ITS YOUNG ATTACHED TO ITS SKIN.

(From *Evolution of Sex*; after *Challenger* Narrative.)

sheath or cuticle of a material called chitin, and this firm sheath explains the need for the limbs being well-jointed. The chitin seems antagonistic to the occurrence of ciliated cells, for none occur in this large series except in the strange type *Peripatus*. Moulting or cuticle-casting is general throughout the series, being necessitated by the fact that the cuticle is non-cellular (and often quite rigid) and cannot grow of itself. As the body grows, it has to be cast and a new one made. Finally, Arthropods have a nervous system like that of Annelids —a double dorsal brain connected by a ring round the gullet with a double chain of ganglia along the ventral surface. But the life of most Arthropods is more highly pitched than that of Annelids. The sense-organs are more highly developed, brains are larger and more complex, the ganglia of the ventral chain tend to become concentrated; there is division of labour among the appendages; there are new internal organs such as a heart; the whole body is better knit together. A crayfish may part with a limb and grow another in its place, but the animal will not survive being cut across the middle as some kinds of Annelids do.

The series includes several classes :—

Crustacea, almost all aquatic, and breathing by gills.

Onychophora, represented by *Peripatus* and other genera.

Centipedes or Chilopoda, Millipedes or Diplopoda, often united as Myriopods.

Insecta, more or less aerial.

Arachnida, spiders, scorpions, mites, etc.

Crustacea.—Except the wood-lice, which live under bark and stones, the land-crabs which visit the sea only at the breeding time, and some shore-forms which live in great part above the tidemark, the Crustaceans are aquatic animals, and usually breathe by gills. Each segment of the body usually bears a pair of appendages, and each appendage is typically made up of a basal piece (protopodite) and two branches (exopodite to the outside and endopodite towards the middle line). Among these appendages much division of labour is often exhibited,

some being sensory, others masticatory, others locomotor, and so on. The presence of two pairs of antennæ on the head is very characteristic. To the chitin or organic foundation of the cuticle carbonate of lime is often added in abundance, as is familiarly seen in the hard shells of crabs and lobsters. In the higher forms the life-history

FIG. 71.—NAUPLIUS OF SACCULINA, SEEN FROM BELOW. ENORMOUSLY ENLARGED.

(From Fritz Müller.)

is often long and circuitous, with a succession of larval stages.

The lower Crustaceans are grouped together as Entomostraca. They are often small and simple in structure; the number of segments and appendages varies greatly. The little larva which hatches from the egg is usually a "Nauplius"—an unsegmented creature with only three pairs of appendages and a median eye. (See fig. 71.)

The brine-shrimps (*Artemia*), the related genus *Bran-*

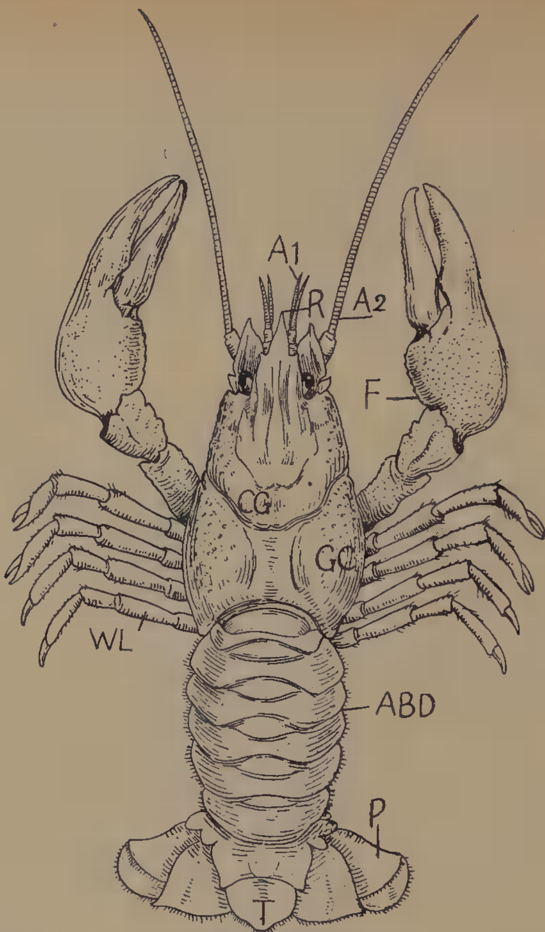


FIG. 72.—DIAGRAM OF THE EXTERNAL FEATURES OF THE FRESHWATER CRAYFISH, *Astacus fluviatilis*.

The student is recommended to take as a simple practical lesson a careful study of this or some similar type. See Huxley's *Crayfish—an Introduction to Zoology*.

At the anterior end in front of the stalked eyes is the rostrum (*R*). The antennules (*A*1) bear tactile and olfactory setæ and have a balancing ear at their base. The long antennæ are organs of touch. Then, on the under surface, there are six pairs of appendages (mandibles, two pairs of maxillæ, and three pairs of maxillipedes) crowded around the mouth.

The cervical groove (*CG*) is the boundary-line between the head portion of the crayfish and the thorax portion. The shield that covers both these parts is called the cephalothoracic shield. Its posterior side-flaps (*GC*) form the gill-covers protecting the eighteen pairs of gills.

The forceps (*F*) and the walking legs (*WL*) are obvious. The posterior part of the body, called the abdomen (*ABD*), consists of six segments and a terminal plate or telson (*T*), on the ventral surface of which the food-canal ends. On the underside of the abdomen there are appendages called swimmerets, and the last or nineteenth pair of appendages form the paddles (*P*) on each side of the telson.

chipus, the old-fashioned freshwater *Apus*; the common water-flea *Daphnia* and its relatives, like *Leptodora* and *Moina*, are united in the order of Phyllopods.

Other small "water-fleas," of which *Cypris* is a very common representative, and which are very abundant in sea and lake, form the order of Ostracods.

Another "water-flea" *Cyclops* and many more or less degenerate "fish-lice" and other ectoparasites (*e.g. Chondracanthus, Caligus, Lernæa*) are known as Copepods. The free-swimming forms often occur in great swarms and are devoured by fishes, thus playing an important part in the economy of the waters.

The acorn-shells (*Balanus*) crusting the rocks, the barnacles (*Lepas*) pendent from floating "timber," and the degenerate *Sacculina* under the tail of crabs, represent the order Cirripedia.

The higher Crustaceans are grouped together as Malacostraca. The body usually consists of nineteen segments, five forming the head, eight the thorax, six the abdomen or tail. In most cases the larva is hatched at a higher level of structure than the Nauplius represents, but the shrimp-like *Penæus* begins life as a Nauplius while the crab is hatched as a Zoæa, the lobster in a yet higher form, and the crayfish as a miniature adult (fig. 111).

Simplest of these higher Crustaceans, in some ways like a survivor of their hypothetical ancestors, is the marine genus *Nebalia*, but we are more familiar with the Amphipods (*e.g. Gammarus*) which jerk themselves along sideways or shelter under stones both in fresh and salt water. The wood-lice (*Oniscus, Porcellio*, etc.) have counterparts (*Asellus, Idotea*) on the shore, and several remarkable parasitic relatives. Among the highest forms are the long-tailed lobsters (*Homarus, Palinurus*), and crayfishes (*Astacus*), and shrimps (*Crangon*), and prawns (*Palæmon, Pandalus*); the soft-tailed hermit crabs (*Pagurus*); and the short-tailed crabs (*e.g. Cancer, Carcinus, Dromia*).

Onychophora or **Prototracheata.**—This class includes a few archaic types, which like other old-fashioned creatures, are very widely distributed, *e.g.* in Tropical Africa,

South Africa, Tropical America, South America, Tibet, Australia, New Zealand. In the course of ages they have gained very wide representation. Worm-like or caterpillar-like in appearance, with a soft and beautiful skin, with unjointed legs, with the halves of the ventral nerve-cord far apart, and with many other remarkable features, they are of special interest as "synthetic types" combining certain Annelid characteristics with certain Tracheate or insect characteristics. Thus they resemble Annelids in having nephridia, in the muscular ensheathing of the body, in having cilia in the reproductive ducts, and so on, while they resemble Tracheates in having tracheæ (unbranched however), appendages in the service of the mouth, and a long tubular heart. They are shy, nocturnal, quickly-moving creatures, living a "cryptozoic" life under leaves and among rotten wood. They snare insects by squirting jets of slime from a pair of papillæ beside the mouth. All are viviparous.

Myriopods.—Under this title are included the centipedes (Chilopoda), flattened, carnivorous, and poisonous,

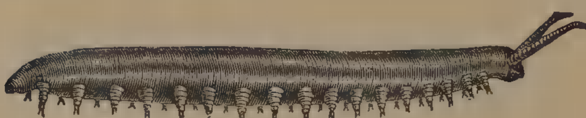


FIG. 73.—PERIPATUS.
(From Chambers's *Encyclop.*; after Moseley.)

the millipedes (Diplopoda), cylindrical, vegetarian, and harmless, and some more primitive less familiar types. The millipedes have on most of the rings two pairs of appendages and, corresponding to this, two pairs of nerve-centres and breathing openings. It cannot be said that they are nearly related to centipedes, and the resemblance between the two types is one of "convergence," *i.e.* it is due to similar adaptations to similar conditions of life. Practically, it is important to remember that killing centipedes usually means killing creatures which destroy injurious insects.

Insecta.—Insects are the birds of the backboneless

series. Like birds, they are on an average active, most have the power of flight, many are gaily coloured, sense-organs and brains are often highly developed.

Contrasted with Onychophora and Myriopods, they have a more compact body, with fewer but more efficient limbs. They are Arthropods which are usually winged in adult life, breathe air by means of tracheæ, and have frequently a metamorphosis in their life-history. To this definition must be added the anatomical facts that the adult body is divided into three regions, (1) a head with three pairs

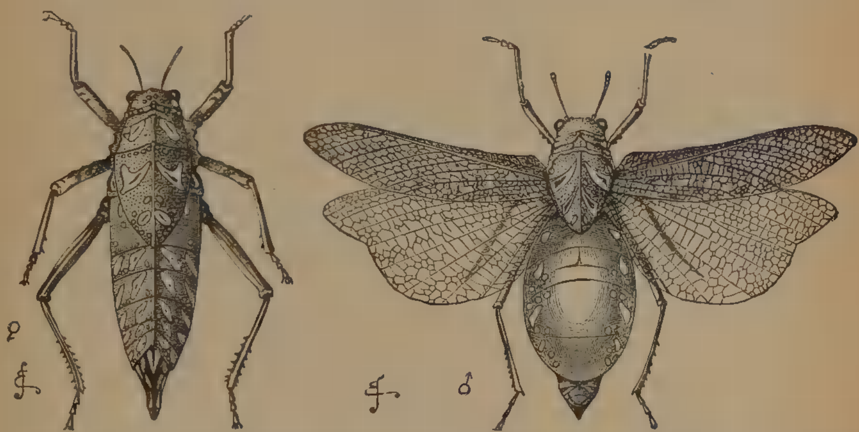


FIG. 74.—WINGED MALE AND WINGLESS FEMALE OF PNEUMORA, A KIND OF GRASSHOPPER.

(From Darwin.)

of mouth-appendages (= legs) and a pair of sensitive outgrowths (antennæ or feelers) in front of the mouth, (2) a thorax with three pairs of walking legs, and usually two pairs of wings, and (3) an abdomen without appendages, except in so far as these may be represented by occasional stings, egg-laying organs, etc.

The wings are very characteristic. They are flattened sacs of skin, into which air-tubes, blood-spaces, and nerves extend. It is possible that they had originally a respiratory, rather than a locomotor function, and that increased activity induced by bettered respiration made them into flying wings.

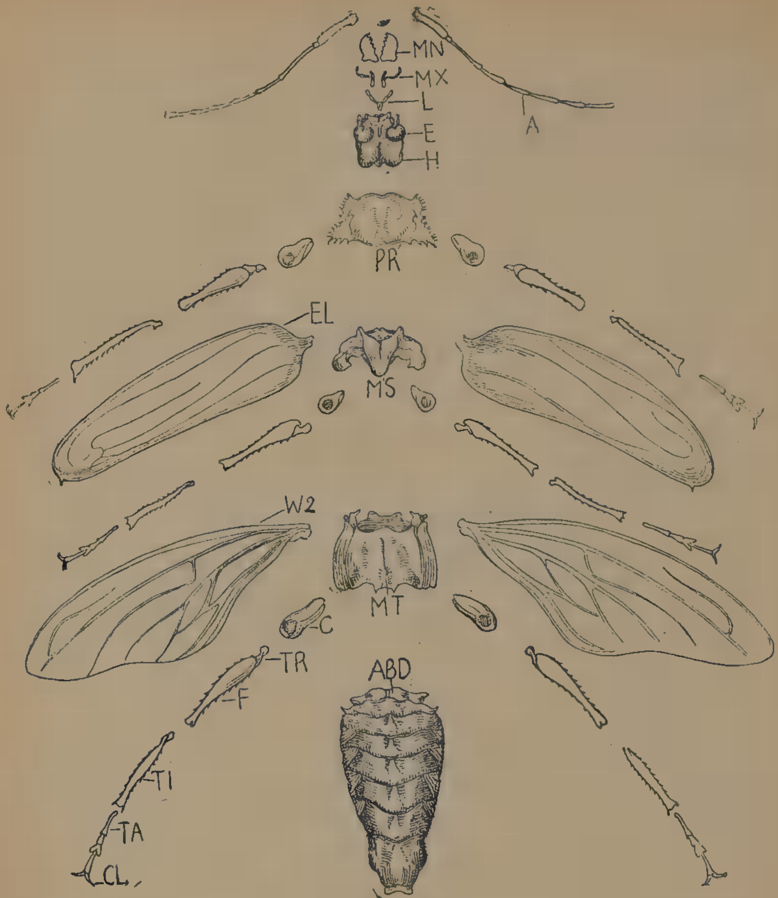


FIG. 75.—EXTERNAL FEATURES OF A DISARTICULATED BEETLE—A STUDY OF AN EXOSKELETON.

The head (*H*) consists of six or seven fused segments, surrounded by coalesced chitinous plates. It bears the compound eyes (*E*), the pre-oral antennæ (*A*), and, beside the mouth, the strong biting mandibles (*MN*), the first maxillæ (*MX*), and the second maxillæ which fuse to form the labium (*L*).

The second great division of the body is the thorax, which consists of three segments, each with a pair of walking legs. First is the prothorax (*PR*); then the mesothorax (*MS*) with the first pair of wings turned into heavy wing-covers or elytra; then the metathorax (*MT*) with the second pair of wings which strike the air in flight.

The parts of an insect's leg are shown,—the coxa (*C*), the minute trochanter (*TR*), the femur (*F*), the tibia (*TI*), the tarsus (*TA*, with four or five joints, the last of which bears the claws (*CL*).

The third great division of the body is called the abdomen; it has seven or eight segments, but no appendages.

The breathing is effected by means of the numerous air-tubes or tracheæ which open externally on the sides and send branches to every corner of the body. As the air is thus taken to all the tissues, the blood-vascular system has little definiteness, though there is (as in other

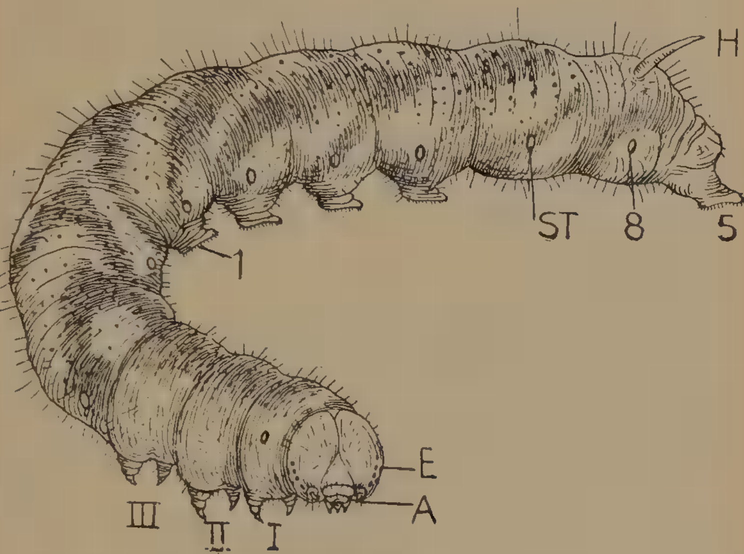


FIG. 76.—THE LARGE CATERPILLAR OF A SPHINGID MOTH, NATURAL SIZE.

The student will find it a profitable practical exercise to make a careful study of the external features of a large caterpillar. The head consists of a number of fused segments, in great part enclosed in two large epicranial plates, which bear half a dozen pairs of simple eyes (*E*). Between the epicranial plates in front is a triangular clypeus, which bears the upper lip or labrum. Posterior to the labrum are two strong mandibles. Behind the mouth the first and second maxillæ have united in a lobed plate. The antennæ (*A*) are three-jointed, but very small.

It is interesting to contrast the head of the caterpillar with the head of the moth, *e.g.* the minute antennæ with the long antennæ, the simple eyes with the compound eyes, the strong mandibles with the vestigial mandibles.

Behind the head are thirteen segments with a much softer cuticle. The first three correspond to the thorax of the adult and each bears (I, II, III) a pair of five-jointed clawed legs, which correspond to the legs of the adult. The first segment bears two breathing apertures or stigmata, which are not present in this segment of the adult.

On the region corresponding to the abdomen there are eight pairs of stigmata (*ST*) leading into the air-tubes or tracheæ. The eighth abdominal segment bears a curious dorsal horn (*H*), the ninth segment is inconspicuous externally, having been in part telescoped. Setæ and pigment spots are seen on the cuticle.

The first two abdominal segments have no appendages. The next four have unjointed, unclawed "pro-legs," with a chitinous gripping plate. The first is marked by the figure 1. There are no appendages on segments 7, 8, 9. On the last, the tenth, there is a pair of anal pro-legs, marked 5.

Arthropods) a dorsal contractile heart. The larvæ of some insects, *e.g.* dragonflies, mayflies, etc., live in the water, and the tracheæ cannot open to the exterior (else the creature would drown), but they are sometimes spread out on wing-like flaps of skin ("tracheal gills"), or arranged around the terminal portion of the food-canal in which currents of water are kept up.

The student should learn something about the different mouth-organs of insects and the kinds of food which they eat; about the various modes of locomotion, for insects "walk, run, and jump with the quadrupeds, fly with the birds, glide with the serpents, and swim with the fish"; about the bright colours of many, and the development of their senses.

In the simplest insects—the old-fashioned wingless Thysanura and Collembola—the young creature which escapes from the egg-shell is a miniature adult. There is no metamorphosis. So with cockroaches and locusts, lice and bugs; except that the young are small, have undeveloped reproductive organs, and have no wings, they are like the parents, and all the more when the parents (*e.g.* lice) also are wingless.

In cicadas there is a slight but instructive difference between larvæ and adults. The full-grown insects live among herbage, the young live in the ground, and the anterior legs of the larvæ are adapted for burrowing. Moreover, the larval life ends in a sleep from which an adult awakes. But much more marked is the difference between the aquatic larvæ of mayflies and dragonflies and the aerial adults, in which we have an instance of more thorough though still incomplete metamorphosis.

Different, however, is the life of all higher insects—butterflies and beetles, flies and bees. From the egg-shell there emerges a larva (maggot, grub, or caterpillar), which often lives an active voracious life, growing much, and moulting often. Rich in stores of fatty food, it falls into a longer quiescence than that associated with previous moults and becomes a pupa, nymph, or chrysalis. In this stage, often within the shelter of a silken cocoon, great transformations occur; the body is undone and

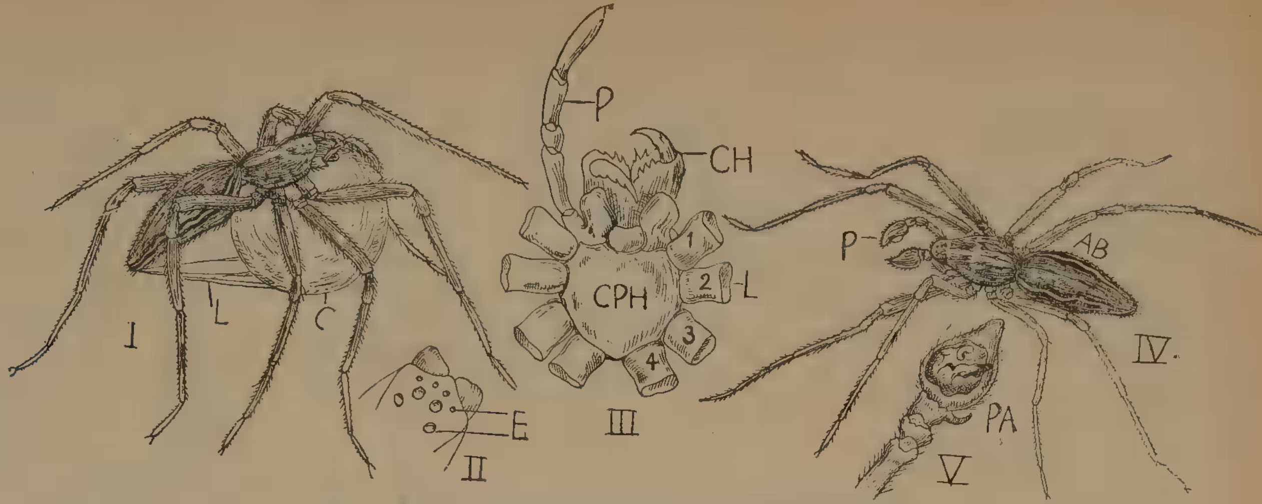


FIG. 77.—STRUCTURE OF A SPIDER (*Dolomedes mirabilis*).

(After Blackwall.)

I. A female, with a silken cocoon (*C*) containing eggs or young spiders. She holds it beneath her cephalothorax (the head portion and the thorax portion fused), and it is also fastened by threads (*L*) to the tip of the abdomen where the spinnerets are situated. There are four pairs of seven-jointed legs, terminally clawed.

II. Dorsal surface of the spider's head showing four pairs of simple, very short-sighted eyes (*E*) of two sizes.

III. The under-surface of the cephalothorax (*CPH*) of a female, showing the bases (1–4) of the walking legs (*L*); the pre-oral cheliceræ containing a poison-gland, the secretion of which passes out at the tip; and the six-jointed pedipalps (*P*) which are mainly tactile, while their bases help in mastication. The cheliceræ, or falces, have two joints, the distal one shutting down on the proximal one, somewhat after the fashion of a half-open penknife suddenly closed.

IV. The male, showing the ends of the pedipalps (*P*) swollen to form a reservoir for the male elements or spermatozoa, which are stored there after emission. Later on the pedipalp is used to transfer the sperms to the receptaculum seminis of the female, whence eventually they reach the ova in the oviducts. *AB*, the abdomen.

V. The end of the male pedipalp (*PA*), much enlarged. It has a complex structure.

rebuilt, wings bud out, the appendages of the adult are formed, and out of the pupal husk there emerges an imago, an insect fully formed.

Arachnida.—Spiders, Scorpions, Mites, etc.—This class is unsatisfactorily large and heterogeneous. In many the body shows two regions, (1) the fused head and breast (cephalothorax), with two pairs of mouth parts and four pairs of walking legs, and (2) the abdomen with no appendages. Respiration may be effected by the skin in some mites, by tracheæ in other mites, by tracheæ plus "lung-books" in many spiders, by "lung-books" alone in other spiders, by "gill-books" in the divergent king-crab (*Limulus*).

The scorpions with a poisoning weapon at the tip of the tail (see fig. 7), the little book-scorpions (*Chelifer*), the long-legged harvest-men (*e.g. Phalangium*); the spiders proper—spinners, nest-makers, hunters; the mites, and many other types are ranked as Arachnids. The quaint king-crab (*Limulus*)—last of a lost race—has some affinities with scorpions and with the extinct Eurypterids. The ancient Trilobites, which lasted from the Cambrian to the Carboniferous, exhibit some affinities with the king-crab, but the nature of the limbs and the presence of antennæ suggest relationship with Crustaceans.

7. **Molluscs.**—It seems strange that animals, the majority of which are provided with hard shells of lime, should be called *mollusca*; for that term first used by Linnæus is a Latinised version of the Greek *malakia*, which means soft. Aristotle applied it originally to the cuttlefish, which are practically without shells, so that its first use was natural enough, but the subsequent history of the word has been strange.

Cockle, mussel, clam, and oyster; snail and slug, whelk and limpet; octopus, squid, and pearly nautilus; what common characteristics have they? Most of them have a bias towards sluggishness, and on the shields of lime which most of them bear, do we not read the legend, "castles of indolence"? But this sluggishness is only an average character, and the shell often thins away. The scallop (*Pecten*) and the swimming

Lima are active compared with the oyster, and they have thinner shells; the sea-snails which creep between tide-marks or on the floor of the sea are heavily weighted, while the sea-butterflies (Pteropods) have light shells, and most cuttlefish have none at all.

The shell is very distinctive. In most of the embryo molluscs which have been studied there is a little pit or "shell-gland" in which a shell begins to be formed, but the shell of the adult is in all cases made by a single or double fold of skin known as the "mantle." In some cases where the shell seems to be absent, *e.g.* in some

Fig. 78.—The Roman Snail (*Helix pomatia*), one of the Terrestrial Air-breathing [Pulmonate] Gasteropods.

It creeps along on its flat muscular ventral surface, the so-called foot (*F*). The head bears retractile long horns (*LH*) with an eye (*E*) at the tip, and retractile short horns (*SH*). The breathing opening is on the right-hand side near the mouth of the shell and the food-canal ends at the same place.

slugs, a vestige is still to be found beneath the skin, while in other cases (*e.g.*, the Octopus) there is no trace left. There are two or three primitive forms (*Chætoderma*, *Neomenia*) where an incipient shell is represented only by a few spicules or plates of lime.

The shell is a non-living product of the skin; it consists for the most part of carbonate of lime along with a complex organic substance called conchin or conchiolin; it shows typically three layers, of which the

outermost is somewhat soft and without lime, while the innermost shines with mother-of-pearl iridescence. Between the two is the prismatic layer with the lime laid down in prisms. Unlike the shell of Arthropods that of molluscs does not require to be moulted as the animal grows, for it is always being added to at the margin.

Most molluscs are marine, on the shore, in the open

FIG. 79.—A DARK VARIETY OF THE GREY SLUG (*Limax maximus*), TO BE CONTRASTED WITH A SNAIL (*Helix*).

The shell in this form is represented by a thin plate concealed beneath the mantle (*M*), which encloses a pulmonary or respiratory chamber. In the Black Slug, *Arion ater*, there is no vestige of a shell. In *Helix* the anterior margin or "collar" of the mantle secretes the shell. The short horns (*SH*) and the long horns (*LH*), with the eyes at the tip, are clearly shown.

sea, in the great depths; there are also many freshwater forms, *e.g.* the mussels *Anodon* and *Unio*, and the snails *Limnæa*, *Planorbis*, and *Paludina*; the terrestrial snails and slugs are legion. Among molluscs of the shore the naked Nudibranchs are often in colour and form protectively adapted to their surroundings; those of the open sea (Heteropods, Pteropods, and many

cuttlefish) are active and carnivorous, with light shells or none; in the dark depths many are blind or with rudimentary eyes, but food seems to be so abundant that there is almost no need to struggle for it.

As to diet, there are three kinds of eaters—carnivores, such as the active swimmers we have mentioned, besides the whelks and many other burglars who bore through

Fig. 80.—The Common Octopus.
(From Chambers's *Encyclop.*; after Brehm.)

their neighbours' shells, and the *Testacella* slugs; vegetarians, like the periwinkle, the snail, and most slugs; and thirdly, almost all the bivalves, which feed on microscopic plants and animals, and on organic débris wafted to the mouth by the lashing of the cilia on the gills and lips. In this connection it is important to notice that all molluscs except bivalves have in their mouths a rasping ribbon or toothed tongue (*radula*, *odontophore*) by which they grate, file, or bore with marked effect. Of parasites there are few, but one Gasteropod, *Entoconcha*

mirabilis, which lives inside the Holothurian *Synapta*, is very remarkable in its degeneration. It starts in life as a vigorous embryo like that of most marine snails; it becomes a mere sac of reproductive organs and germ-cells.

In structure, molluscs differ remarkably from the arthropods and higher "worms" in the absence of segments and serial appendages.

To begin with, they were doubtless bilaterally symmetrical animals, and this symmetry is retained in primitive forms like the eight-shelled *Chiton* and in the bivalves and cuttlefishes. But most of the snails are twisted and lop-sided, they cannot be symmetrically halved. That this lop-sidedness is not necessarily a defect, but rather the reverse, is evident from the success not only of the snail tribe, but of many other asymmetrical animals.

The skin has a remarkable fold (double in the bivalves) known as the "mantle," the importance of which in making the shell we have already recognised. Another very characteristic structure is the so-called "foot," a muscular protrusion of the ventral surface, an organ used in creeping and swimming, leaping and boring, but almost absent in the sedentary oysters.

We rank the molluscs high among backboneless animals, partly because of the nervous system, which here as elsewhere is a dominating characteristic. There are fewer nerve centres than in most Arthropods or in higher "worms," but this is in most cases a sign of concentration. There is a (*cerebral*) pair with nerves which supply the head region, another (*pleural*) pair with nerves to the sides and viscera, a third (*pedal*) pair whose nerves govern the foot, and often other accessory centres of which the most important are *visceral*. In the somewhat primitive eight-shelled *Chiton* and its neighbours, the nervous system is the most readily harmonised with that of other Invertebrates; in bivalves the three pairs of centres are far apart; in most snails and in cuttlefish the three are concentrated in the head-region. Some of the forms with concentrated ganglia show signs of cleverness and emotion.

Many molluscs pass through two larval stages before they acquire their characteristic adult appearance. The first is interesting because it is virtually the same as the young stage of many marine Annelids. It is a minute barrel-shaped or pear-like creature with a ring of locomotor cilia in front of the mouth, and is known as a *Trochosphere.*

After a while this changes into a more characteristic form called the *Veliger.* It bears on its head a ciliated cushion or velum often produced into lobes; the body has a ventral "foot" and a dorsal "shell-gland." In aquatic Gasteropods the visceral hump begins to appear at this stage.

FIG. 81.—A DEEP-SEA CUTTLEFISH (After Chun.)

One of the remarkable adaptations is the development of so-called "telescope" eyes, probably suited for making the most of the dim light.

The eggs of cuttlefish differ from those of other molluscs in their rich supply of yolk, which serves for a prolonged period as capital for the young, and the two larval stages noticed above are skipped over. In land snails and slugs, what comes out of the egg is

a miniature of the adult. There are other interesting modifications in the life-history of freshwater forms, witness the little larvæ (Glochidia) of the freshwater mussels which are kept within the gills of the mother till the approach of a minnow, stickleback, or some other fish, to which the liberated young then fix themselves. After sojourning for a time on the fish, the young mussels undergo a metamorphosis and drop off to begin an independent life, often far from their birthplace.

CHAPTER XIII

BACKBONED ANIMALS

1. Enteropneusts—2. Tunicates—3. Lancelets—4. Round-mouths or Cyclostomes—5. Fishes—6. Amphibians—7. Reptiles—8. Birds—9. Mammals.

According to Aristotle, fishes and all higher animals were "blood-containing," and thus distinguished from the lower animals, which he regarded as "bloodless." He was mistaken as to the absence of blood in lower animals, for in most it is present, but the line which he drew between higher and lower animals has been recognised in all subsequent classifications. Fishes, amphibians, reptiles, birds, and mammals differ markedly from molluscs, insects, crustaceans, "worms," and yet simpler animals. The former are backboned (Vertebrate), the latter backboneless (Invertebrate).

It is necessary to make the contrast more precise. (*a*)

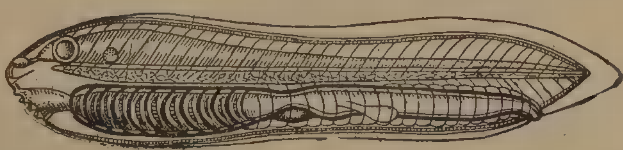


Fig. 82.—Diagram of "Ideal Vertebrate," showing the Segments of the Body, the Spinal Cord, the Notochord, the Gill-clefts, the Ventral Heart.

(After Haeckel.)

Many Invertebrates have a well-developed nerve-cord, but this lies on the ventral surface of the body, and is connected anteriorly, by a ring round the gullet, with a dorsal brain in the head. In Vertebrates the whole of the central nervous system lies along the dorsal surface

of the body, forming the brain and spinal cord. These arise by the infolding of a skin groove on the dorsal mid-line of the embryo. (*b*) Underneath the nerve-cord in the Vertebrate embryo is a supporting rod or notochord. It arises along the roof of the food-canal, is therefore of endodermic origin, and serves as a supporting axis to the body. It persists in some of the lowest Vertebrates (*e.g.* the lancelet); it persists in part in some fishes, *e.g.* mud-fishes; but in most Vertebrates it is replaced by a meso-dermic growth—the backbone—which ensheaths and constricts it. (*c*) From the anterior region of the food-canal in fishes and tadpoles, slits, bordered by gills, open to the exterior. Through the slits water flows, washing the outsides of blood-vessels and aerating the blood. These slits or clefts occur on the neck-region of all young Vertebrates, but in reptiles, birds, and mammals they are transitory and never used, except that the first one becomes the Eustachian tube leading from the ear-passage to the back of the mouth. Amphibians are the highest animals in which gill-slits are used for breathing, and even then they may be entirely replaced by lungs in adult life. They are evident in tadpoles, they have disappeared in frogs. (*d*) Many an Invertebrate has a well-developed heart, but this always lies on the dorsal surface of the body, while that of fish or frog, bird or man, lies ventrally. (*e*) It is characteristic of the eye of backboned animals that the greater part of it arises as an outgrowth from the brain, while that of backbone-less animals is directly derived from the skin. But this difference is less striking when we remember that it is from an infolding of skin that the brain of a back-boned animal arises.

But while the characteristics of backboned animals can be stated with some precision, it is not possible to draw with a firm hand the dividing line between backboned and backboneless. Thus fishes are not the simplest Vertebrates; the lamprey and the glutinous hag belong to a more primitive type, and are called fishes only by courtesy; simpler still are the lancelets; the Tunicates hesitate on the border line, being tadpole-like in their

youth, but mostly degenerate when adults; and the worm-like *Balanoglossus* and its allies may be plausibly ranked as incipient Vertebrates.

1. **Enteropneusts.**—The term Enteropneusts (gut-breathers) or Hemichorda is applied to *Balanoglossus*, *Ptychodera*, and a number of other genera, of which it is difficult to say whether they are worm-like Vertebrates or Vertebrate-like worms. They occur in many parts of the world, eating their way through the sandy mud off the coasts. The body of *Balanoglossus* and its relatives is ciliated and divided into distinct regions—a large "proboscis" in front of the mouth, a firm collar behind the mouth, a part with numerous gill-slits behind the collar, and finally a soft coiled portion with the intestine

FIG. 83.—BALANOGLOSSUS, SHOWING PROBOSCIS, COLLAR, AND GILL-SLITS.

and reproductive organs. The size varies from about an inch to several feet, the colours are bright, the odour is peculiar; the sexes are separate. Enteropneusts are especially remarkable in having a dorsal supporting rod (like a notochord) in the "proboscis" region, a dorsal nerve-cord running along the back and especially developed in the collar, and numerous gill-slits opening dorsally from the anterior part of the food-canal. It may be, however, that the short supporting rod of the proboscis is only an analogue, not a homologue (see chap. XI), of the notochord of the indubitable Vertebrates, and the morphological importance of the dorsal nerve-cord is considerably lessened when we discover that there is a ventral one as well. Both are in fact but condensations of a network of nerve-cells and nerve-fibres extending diffusely underneath the skin. Perhaps the most satisfactory evidences of Vertebrate affinities are to be found in the gill-slits and the way in which the

body-cavity develops as five pockets from the primitive gut. In any case, it is difficult not to include *Balanoglossus* and its allies in the Vertebrate or Chordate series, and the same may be said of another strange animal, *Cephalodiscus*, first discovered by the *Challenger* explorers.

2. **Tunicates.**—Hanging to the pennon-like seaweeds which fringe the rocky shore and are rarely uncovered by the tide, large sea-squirts sometimes live. They are shaped like double-mouthed wine-bags, 2 or 3 inches in length, and water is always being drawn in at one aperture and expelled at the other. Usually they live in clusters, and their life is very passive. We call them sea-squirts because water may spout forth when we squeeze their bodies, while the title Tunicate refers to a characteristic cloak or tunic which envelops the whole animal (fig. 85).

FIG. 84.—CEPHALODISCUS, A SINGLE INDIVIDUAL, ISOLATED FROM A COLONY. IT IS MUCH MAGNIFIED.

(From Chambers's *Encyclop.*; after *Challenger* Report, by M'Intosh and Harmer.)

There is not much to suggest backbonedness about these Tunicates, and till 1866 no one dreamt that they could be included in the Vertebrate series. But then the Russian naturalist Kowalevsky discovered their life-history. The young forms are free-swimming creatures like miniature tadpoles, with a dorsal nerve-cord and brain, a supporting axis or notochord in the tail region, gill-slits opening from the pharynx, a little eye arising as an outgrowth of the brain, and a ventral heart.

There are only two or three genera of Tunicates, especially one called *Appendicularia*, in which these Vertebrate characteristics are retained throughout life. The others lose them more or less completely. The young Tunicates are active, perhaps too active, for a short time; then they settle down as if fatigued, fix themselves by their heads, absorb their tails, and become deformed. The nervous system is reduced to a single ganglion between the two apertures; the original gill-slits are replaced by numerous secondary slits making the pharynx like a basketwork; the eye is lost. From the skin of the degenerate animal the external tunic is secreted. Though cells may eventually migrate into it, it is, to begin with, a mere cuticle (*i.e.* a non-cellular, non-living layer), and consists, in part at least, of cellulose, the substance which forms the cell-walls of plants. Thus this characteristically vegetable substance occurs almost uniquely in the most passive part of a very passive animal. The sea-squirt's metamorphosis is one of the most signal instances of individual retrogression; the larva is in general architectural plan on a higher grade than the adult, which is not inconsistent with the fact that some structures in the adult, such as

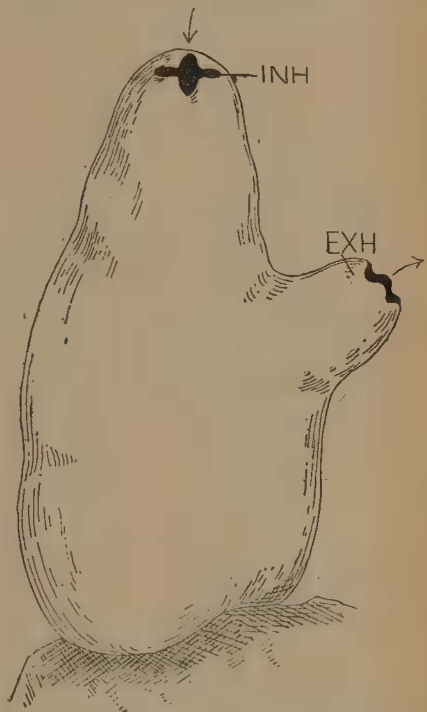


FIG. 85.—THE EXTERNAL APPEARANCE OF AN ASCIDIAN, SHOWING THE INHALANT APERTURE (*INH*) AND THE EXHALANT APERTURE (*EXH*).

The body is covered by a thick tunic, mainly composed of cellulose. It is fastened below to a stone. The figure is about half the size of the specimen drawn.

the pharynx, are very complicated as compared with their condition in the larva; the young Tunicate is a Vertebrate, the adult is a nondescript.

Tunicates are hermaphrodite—a very rare condition among Vertebrates; some of them exhibit "alternation of generations," as the poet Chamisso first observed; asexual multiplication by budding is very common, and not only clusters but more or less intimate colonies are thus formed. A few are free-swimming, such as the fire-flame (*Pyrosoma*), a unified colony of tubular form, sometimes 2 or 3 feet in length, and brilliantly phosphorescent. Very beautiful are the swimming chains of the genus *Salpa*, whose structure and life-history alike are complicated.

3. **Lancelets.**—The third step on the Vertebrate ladder is occupied by the lancelets or Cephalochorda (*Amphioxus* and two or three other genera). They are fish-like in form, about two inches in length, and are widely distributed on the sandy coasts of warm and temperate seas. They live rather sluggishly in fine sand and feed on microscopic organisms and particles wafted into the mouth.

From tip to tail of the translucent body runs a supporting notochord; above this is a spinal cord, with hardly a hint of brain. The pharynx bears a hundred or so gill-slits, which in the adult are covered over in a rather complex way, so that the water which enters by the mouth finds its way into an atrial chamber, as in Tunicates, and thence out by a single aperture towards the posterior end. Although Amphioxus has no skull, nor jaws, nor brain, nor limbs, it deserves its position near the base of the Vertebrate series. The sexes are separate, and the eggs are fertilised outside of the body. The development of the embryo has been very carefully studied, and is for a time very like that of Tunicates.

4. **Round-mouths or Cyclostomata.**—The hag-fishes and the lampreys and a few allied genera must be excluded from the class of fishes. They are survivors of a more primitive race. They are jawless, limbless, scaleless, and therefore not fishes.

The lampreys (*Petromyzon*) live in rivers and estuaries, and also in the wider sea. They are eel-like, slimy animals. The skeleton is gristly; the simple skull is imperfectly roofed; the nostril is unpaired and far back on the head; the rounded mouth has horny teeth on the lips and on the piston-like tongue; there are seven pairs of gill-pouches which open directly to the exterior and internally into a tube lying beneath and communicating with the adult gullet; the young are blind and otherwise different from the parents, and may remain so for two or three years.

Though lampreys eat worms and other small fry, and even dead animals, they fix themselves aggressively to fishes, rasping holes in the skin, and sucking the flesh and juices. They also cling to stones, as the name *Petromyzon* suggests.

Some species drag stones into a kind of nest. They spawn in spring, usually far up rivers, for at least some of the marine lampreys leave the sea at the time of breeding. The young are in many ways different from the parents, and that of the small river lampern (*Petromyzon branchialis*) used to be regarded as a distinct animal—*Ammocœtes*. The metamorphosis was discovered two hundred years ago by Baldner, a Strasburg fisherman, but was overlooked till the strange story was worked out in 1856 by August Müller. Country boys often call the young lampreys "nine-eyes," and the Germans also speak of *Neun-augen*.

The sea lamprey (*P. marinus*) may measure three feet; the river lamprey (*P. fluviatilis*) about two feet; the small lampern or stone-grig (*P. branchialis* or *planeri*) about a foot. The flesh is well known to be palatable.

The glutinous hag (*Myxine glutinosa*) is an eel-like animal, about a foot in length, of a livid flesh colour. It is common at considerable depths (40 to 300 fathoms) off the coasts of Britain and Norway, and, when not feeding, lies buried in the mud with only its nostril protruded. Like the lamprey, it has a smooth slimy skin, a gristly skeleton, a round suctorial mouth with teeth. The single nostril communicates with the food-

canal at the back of the mouth, and serves for the inflowing of water; the six gill-pockets on each side open directly into the gullet, but each has an excurrent tube, and the six tubes of each side open at a common aperture. The animal lives away from the light, and its eyes are rudimentary, hidden beneath skin and muscles. The skin of the irritated animal exudes so much slime that the ancients spoke of the hag "turning water into glue."

In several ways the hag is strange. Thus J. T. Cunningham discovered that it is hermaphrodite, first producing male elements, and afterwards eggs, and Nansen has corroborated this. The eggs are large and oval, each enclosed in a "horny" shell with knotted threads at each end, by which a number are entangled together. How they develop is unknown. The hags devour the bait and even the fish from the fisherman's lines, and three or four are sometimes found inside a hooked fish.

5. **Fishes.**—Fishes are in the water as birds in the air—swift, buoyant, and graceful. They are the first backboned animals with jaws, while scales, paired fins, and gills are their most characteristic structures. The scales may be hard or soft, scattered or closely fitting, and are often very beautiful in form and colour. The paired fins are limbs, as yet without digits, varying much in size and position, and helping the fish to direct its course. The gills are feathery outgrowths of the wall of the pharynx bordering the gill-clefts, and supported by gill-arches. They afford a large surface on which the blood-vessels are washed by the water. They are the breathing organs of all fishes, but in the double-breathing mud-fishes (Dipnoi) the swim-bladder has come to serve as a lung, and there are hints of this in a few others.

There are several subdivisions of fishes:—

(1) The cartilaginous fishes (Elasmobranchs or Selachians) are for the most part quite gristly, except in teeth and scales. Among them are the flattened skates and rays with enormous fore-fins, while the sharks and dogfish are shaped like most other fishes. Their pedigree goes back as far as the Silurian rocks, in which remains of shark-like forms are found. A Japanese shark (*Chla-*

FIG. 86.—EXTERNAL FEATURES OF A SKATE (*Raia batis*)—ONE OF THE ELASMOBRANCH OR CARTILAGINOUS FISHES.

The figure also shows (III) a mermaid's purse or skate's egg-case and (IV) a skate-leech.

I. Dorsal surface of the skate. *F*, the anterior fontanelle or unroofed part of the skull. The posterior fontanelle is between the two eyes. Behind the eyes, a spiracle (*SP*), a gill-cleft turned dorsally, by which water enters, passing out by the gill-clefts (*GS*) on the ventral surface. *SC*, the supra-scapulæ, two cartilages by which the pectoral girdle, supporting the huge pectoral fins (*PC*) is attached to the backbone. *PV*, the pelvic fins. *CF*, the reduced unpaired caudal fin.

II. Ventral surface. *NB*, the naso-buccal groove, like hare-lip, running from the nostril to the corner of the mouth. *GS*, 5 pairs of gill-slits. *CL*, the aperture of the cloaca, a common chamber receiving the end of the food-canal (rectum), the ureters from the kidneys, and the genital ducts. *AP*, abdominal pores leading into the body-cavity.

III. The mermaid's purse, made of horn or keratin, shows tendrils (*T*) for attachment to sea-weed. It is opened to show the large egg (*E*).

IV. The skate-sucker, *Pontobdella muricata*, a marine leech. *H*, the head end; *S*, the posterior sucker.

mydoselachus) is said to be very closely allied to types which occur in the Old Red Sandstone. Allied to the Elasmobranchs, but sometimes kept in a separate division, are two genera, the *Chimæra* or King-of-the-Herrings, and *Callorhynchus*, its relative in Southern Seas. The Elasmobranchs stand somewhat apart from other fishes.

(2) A very distinct order, now decadent, is that of the Dipnoi or Double-breathers. They do not depend on gills only, for the air-bladder has been turned into a lung. In this and several other ways a transition from Fishes to Amphibians is suggested. There are many extinct representatives, but only three living genera—*Ceratodus* from Queensland rivers, *Protopterus* from West and Tropical Africa, and *Lepidosiren* from the Amazons. Their widely separated geographical representation shows that they are relics of a once widespread stock. Other illustrations of this have already been noticed, *e.g.* Onychophora, Enteropneusts, and Lancelets.

(3) The other fishes are grouped together as Teleostomes. Four sets of them are now represented by (*a*) two "living fossils"—*Polypterus* and *Calamoichthys*—from African rivers; (*b*) the sturgeon tribe; (*c*) the bony pike (*Lepidosteus*) and *Amia* of North America, and (*d*) the modern rank and file of thoroughly bony fishes or Teleosteans. The first three sets are often spoken of as Ganoids. Herring and salmon, cod and pike, eel and minnow, flounder and plaice—in fact all of the common bony fishes—are Teleosteans.

The wedge-like form of most fishes is well adapted for rapid swimming. Most flat fish, whether flattened from above downwards like the gristly skate, or from side to side like the flounders and plaice, live at the bottom; those of eel-like shape usually wallow in the sand or mud; the quaint globe-fish float passively. The chief organ of locomotion is the tail; the paired fins help to raise or depress the fish, and serve as guiding oars. In the climbing perch they are used in scrambling; in the flying fish they serve as parachutes during the long swooping leaps. In eels and pipe-fish they are absent; in the Dipnoi they have a remarkable median axis. The

unpaired fins on the back and tail and under-surface are fringes of skin supported by integumentary skeletal rays or dermotrichia.

Fishes are often resplendent in colours, which are partly due to red, yellow, and black pigment contained in branching amœboid cells (chromatophores), and partly to spangles of a silvery waste-product called guanin, which are also contained in special cells (iridocytes). In

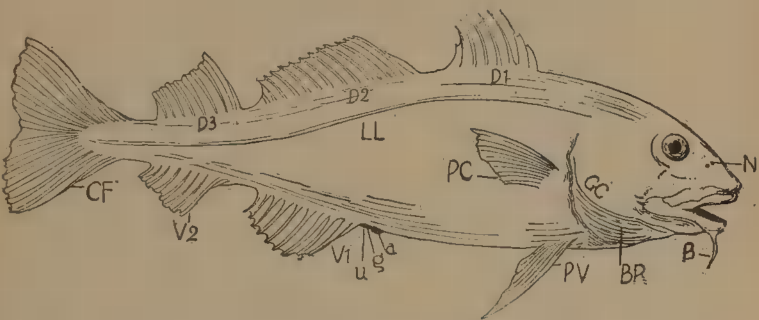


FIG. 87.—EXTERNAL FEATURES OF A COD (*Gadus morrhua*), A TYPICAL TELEOSTEAN FISH.

As a practical exercise the student should verify the various features on a specimen and contrast them with those of a skate.

N, double nasal aperture on each side, of use only in connection with the olfactory sense. Behind the nostril the lidless eye. Behind the eye, deeply embedded in the skull, is the ear with no drum or external aperture. *D*1, *D*2, *D*3, the unpaired dorsal fins, supported by integumentary bony rays or dermotrichia. *CF*, the homocercal or secondarily symmetrical caudal fin. *V*1, *V*2, the unpaired ventral fins. *a*, *g*, *u*, the anus, the genital aperture, and the urinary aperture close together. *LL*, the sensory lateral line.

The posterior body behind a line drawn from *u* to *D*2 is solid muscle, and is the locomotor organ. The muscles are disposed in W-shaped blocks or myotomes separated by connective tissue.

B is a large tactile barbule hanging down below the front of the mandible or lower jaw. *GC*, the gill-cover or operculum, supported by four bones, covering the gill-chamber. Below it the branchiostegal membrane supported by rays (*BR*). *PC*, the pectoral fin or fore-limb ; *PV*, the pelvic, fin or hind-limb, which has been shunted into a jugular position.

many cases fishes can change their coloration so as to bring it into greater harmony with their surroundings. Flat-fishes, like plaice, do this in many cases with great rapidity, while one is looking at them. In other cases, such as trout, the transformation is slow. The outer skin or epidermis of fishes is transparent and so delicate that it comes off on our fingers when we take hold of a

fish. There are sometimes pigment cells in it, but these are mainly or exclusively confined to the under-skin, or dermis, both above and below the scales.

6. **Amphibians.**—The Amphibians of modern times are neither numerous nor large. Giant Amphibians or Labyrinthodonts were in evidence in the Carboniferous period, but most of the modern frogs and toads, newts and salamanders, are relatively pigmies.

FIG. 88.—THE GEMMEOUS DRAGONET (*Callionymus lyra*), THE MALE ABOVE, THE FEMALE BENEATH. A TELEOSTEAN FISH. (From Darwin.)

Amphibians mark a momentous period in the evolution of backboned animals, for they were the first to acquire fingers and toes, genuine lungs, open communications between the nostrils and the mouth, a three-chambered heart, vocal cords, and a mobile muscular tongue. With very few exceptions, young Amphibians breathe by gills, and in some cases these gills persist in adult life. But whether they do or not, the full-grown Amphibians have

normally lungs and use them. The skin is characteristically soft, naked, and clammy. Unpaired fins are sometimes present on the back and tail as in Fishes, but are never supported by fin-rays.

The class includes four orders, of which the Labyrin-

FIG. 89.—THE COMMON FROG (*Rana temporaria*).

The student should verify on a specimen the external features shown in the drawing. When breathing, the frog keeps its mouth tightly shut, and air enters by the paired valved nostrils. The nostrils of fishes are exclusively olfactory; from amphibians onwards they are olfactory and respiratory. The prominent eyes have a distinct upper eyelid, and a very rudimentary lower eyelid, continued, however, into a transparent nictitating membrane, which can be drawn upwards over the eye. The tympanum or drum of the ear is flush with the skin, not sunk inwards as usual. At a certain stage of development in higher vertebrates the drum is on the surface. A hump on the back shows where the hip-girdle is attached to the last free vertebra, the ninth. The frog has an unusually small number of vertebræ and no ribs. There is no thumb. There are no nails or claws. The hind-foot is very long and thus adapted for swimming and leaping. The skin is loose, naked, glandular, pigmented, with absorptive and respiratory functions. All through the winter the frog, buried in the mud, breathes cutaneously.

thodonts are wholly extinct, the other three being represented by tail-less frogs and toads (Anura), by newts and salamanders (Urodela) with distinct tails, and by a few of worm-like form and burrowing habit, *e.g.* *Cæcilia*.

Some, the last for example, are terrestrial, but usually live in damp places; most pass their youth at least in fresh water; none can endure saltness, and they are therefore absent from almost all oceanic islands.

The common British newts (*Triton*), and the often brightly-coloured salamanders (*Salamandra*) have in adult life no trace of gills; the rice-eel (*Amphiuma*) and the allied *Menopoma* lose their gills, but persistent clefts indicate their position; the blanched blind *Proteus* from caves and the genus *Menobranchus* keep their gills throughout life. The remarkable Axolotl from North American lakes occurs in two forms, both of which may bear young; the one form (Axolotl) has persistent gills, the other form (*Amblystoma*) loses them, and the change from the Axolotl to the *Amblystoma* is sometimes induced by scarcity of water. (See p. 390 and fig. 119.)

The common frogs (*Rana*), the Surinam toad (*Pipa*), the common toads (*Bufo*), and the tree-frogs (*Hyla*) illustrate the tailless order Anura. In none of them is there in adult life any trace of gills.

The worm-like, limbless, burrowing Amphibians (Gymnophiona) must not be confused with the blind- or slow-worms, which are lizards. There are only a few genera, *e.g. Siphonops*, *Epicrium*, *Cæcilia*. There are small calcareous scales concealed in transverse rows in the skin. In some forms at least there are gills in the very young stages before hatching, but they do not last. The eyes are minute and covered with skin.

The race of Amphibians began in the Devonian age, and the quite extinct Labyrinthodonts (from Carboniferous to Triassic) had dermal armour and were sometimes of large size.

Amphibians are naturally sluggish. For long periods they can fast and lie dormant; they can survive being frozen quite stiff, and though tales of toads within stones are mostly due to mistakes or fancies, there are some authentic cases of prolonged imprisonment.

Few are found far from water, and the gilled condition of the young is skipped over only in a few cases. In the black salamander (*Salamandra atra*) of the Alps, which

FIG. 90.—LIFE-HISTORY OF THE FROG.

Some clusters of eggs are seen, each egg surrounded by a sphere of jelly, which is in several ways protective, *e.g.* in saving the developing eggs from being crowded and jostled. It is also unpalatable to most water-animals. Each ovum is about a tenth of an inch in diameter; the jelly swells up into a much larger sphere. One of the eggs is shown on a larger scale, with the tadpole ready to emerge.

Hanging on to the water-weed, by means of a glandular adhesive organ, are the newly hatched tadpoles still mouthless, gill-less, and blind.

The tadpole above the figure 2 is about two months old; it is breathing by its second set of gills; the hind-legs have budded out.

The tadpole opposite 3 is nearly three months old. The tail is being absorbed, the lungs have developed, a metamorphosis is being accomplished, after which it leaves the water as a tiny frog (4).

lives where pools are scarce, the young, after breathing by gills for a time within the mother, are born as lung-breathers; also in some species of tree-frogs (*Hylodes*), which live in situations where water is scarce, the gilled stage is suppressed.

The development of the frog (fig. 90) should be studied by every student of natural history. The eggs are fertilised as they are being laid. The division of the ovum can be readily observed. In its early stages the tadpole is somewhat fish-like, for instance in its two-chambered heart and in its circulation; and the mouth reminds one at first of a lamprey's. Its gills are more like the external gills of mud-fishes than the gills of ordinary fishes, and there are two sets of them. When the tadpole is about two months old, it breathes by lungs as well as gills, and comes to the surface to take gulps of air. It is then physiologically like one of the mud-fishes or double-breathers (Dipnoi). Towards the third month—the time varying with the species and the temperature—the gills entirely disappear, the tail is all but absorbed, and a minute lung-breathing frog climbs out of the water. The larva feeds first on its legacy of yolk, then on fresh-water plants, then on small animals or even on its own relatives; then it fasts, absorbing its tail; and finally it becomes an insect-catching frog.

7. **Reptiles.**—Fishes and Amphibians are closely allied; so Reptiles are linked to Birds, and more remotely to Mammals also. Those three highest classes—Reptiles, Birds, and Mammals—are very different from one another, but they have certain characters in common. Most of them have passed from the water to dry land; none of them ever breathe by gills; all of them have two embryonic birth-robes—amnion and allantois—which are of great importance in early life. Compared with the other Vertebrates, the brains are more complex, the circulation is more perfect, the whole life has a higher pitch. As symbols of mammal, bird, and reptile, take the characteristic coverings of the skin—hair, feathers, and scales. Hair typifies strength and perhaps also gentleness; feathers suggest swift flight, the beauty

which wins love, and the down which lines the warm nest; scales speak of armour and cold-blooded stealth.

But we need not depreciate reptiles, nor deny the justice of that insight which has found in them the fittest emblems of the omnipotence of the earth. If Athene of the air possesses the birds, surely the power of the dust is in the grovelling snakes. Few colour arrangements are more beautiful than those which adorn the lithe lizards. The tortoise is an example of passive energy, self-contained strength, and all but impenetrable armature. The crocodiles more than the others recall the strong ferocity of the ancient extinct dragons.

It is interesting to remember the long-tailed toothed *Archæopteryx*, the predecessor of modern birds, and to recall the giant sloths which preceded the modern Edentate mammals; but it is essential to include in our appreciation of Reptiles the giant dragons of their golden age. Most modern forms are pigmies beside an *Ichthyosaurus* 25 feet long, a *Megalosaurus* of 30, a *Titanosaurus* of 50, or an *Atlantosaurus* of 60, all fairly broad in proportion. We have still pythons and crocodiles and other reptiles of huge size, and we do not deny Grant Allen's remark that a good blubbery "right whale" could give points to any deinosaur that ever moved upon Oolitic continents, but the fact remains that in far back times (Triassic, Jurassic, and Cretaceous) reptiles had a golden age with a predominance of forms larger than any living members of the class. Besides size, however, the ancient saurians had another virtue, apparently possessed by both small and great—they were progressive. For it seems certain that birds had their origin from feverish saurians (probably Ornithischian Deinosaurs) which acquired some power of flight, and it is also possible that some mother reptile, retaining her young for a long time within her womb, was the forerunner of the mammalian race.

There are many orders of extinct reptiles—Ichthyosaurs, Plesiosaurs, Deinosaurs, Pterosaurs, and other saurians. The living forms belong to five orders—the lizards, the snakes, the tortoises, the crocodiles, and the archaic

New Zealand "lizard," *Hatteria* or *Sphenodon*, which may almost be called a living fossil.

The Lizards (Lacertilia).—The lizards form a central order of Reptiles, but the members are a motley crowd, varied in detailed structure and habit. Usually active in their movements, though fond, too, of lying passive in the sunshine, they are often very beautiful in form and colour, and sometimes change their tints in sympathetic response to their surroundings or in expression of internal moods. Most lay eggs, but in some, *e.g.* the common British lizard (*Lacerta vivipara*), and the slow-worm, the eggs are hatched within the mother.

Among the remarkable forms are the Geckos, which with plaited adhesive feet can climb up smooth walls; the large Monitors (*Varanus*), which may attain a length of 6 feet, and prey upon small mammals, birds, frogs, fishes, and eggs; the poisonous Mexican lizard (*Heloderma horridum*), with large venom-glands and somewhat fang-like teeth; the worm-like, limbless *Amphisbæna*; the likewise snake-like slow-worm (*Anguis fragilis*), which well illustrates the tendency lizards have to break in the spasms of capture; the large Iguanas, which frequent tropical American forests, and feed on leaves and fruit; the sluggish and spiny "Horned Toad" (*Phrynosoma*); the Agamas of the Old World comparable to the Iguanas of the New; the Flying Dragon (*Draco volans*), which, with skin outstretched on extended ribs, swoops from tree to tree; the Australian frilled lizards (*Chlamydosaurus*), and the quaint thorny *Moloch*; the single marine lizard (*Oreocephalus* or *Amblyrhynchus cristatus*) from the Galapagos; and the divergent Chamæleons, flushing with changeful colour.

The New Zealand *Hatteria* or *Sphenodon* is quite unique, and seems to be the sole survivor of an extinct order—Rhynchocephalia. It was in it first of all that the pineal body—an upgrowth from the brain (third ventricle) of backboned animals—was seen to be like a degenerate upward-looking eye.

Snakes or Serpents (Ophidia).—These much modified reptiles mostly cleave to the earth, though there are

Fig. 91.—The Wall-lizard (*Lacerta muralis*), Three Differently Coloured and Marked Varieties of the same Species.
(Compiled from Eimer.)

among them clever climbers, swift swimmers, and powerful burrowers. Though they are all limbless, unless we credit the little hind claws of some boas and pythons with the title of legs, they flow like swift living streams along the ground, using ribs and scales instead of their lost appendages, pushing themselves forward with jerks so rapid that the movement seems continuous. Without something on which to raise themselves they must remain at least half prostrate, but in the forest or on rough ground there are no lither gymnasts. Their united eyelids give them an unlimited power of staring, and, according to uncritical observers, of fascination; yet most of them seem to see dimly and hear faintly, trusting mainly for guidance to the touch of their restless protrusible tongue and to their sense of smell. Their only language is a hiss or a whine. Most sink into an annual state of torpor, and all periodically cast off the outermost layer of the epidermis, turning it inside-out in a normally continuous slough. Almost all lay eggs, but in a few cases (*e.g.* the adder) the young are hatched within the mothers, and this mode of birth may be induced by artificial conditions. Think not meanly of the serpent, "it is the very omnipotence of the earth. That rivulet of smooth silver—how does it flow, think you? It literally rows on the earth with every scale for an oar; it bites the dust with the ridges of its body. Watch it when it moves slowly—a wave, but without wind! a current, but with no fall! all the body moving at the same instant, yet some of it to one side, some to another, or some forward, and the rest of the coil backwards; but all with the same calm will and equal way—no contraction, no extension; one soundless, causeless march of sequent rings, and spectral procession of spotted dust, with dissolution in its fangs, dislocation in its coils. Startle it—the winding stream will become a twisted arrow; the wave of poisoned life will lash through the grass like a cast lance. It scarcely breathes with its one lung (the other shrivelled and abortive); it is passive to the sun and shade, and cold or hot like a stone; yet 'it can outclimb the monkey, outswim the fish, outleap

the zebra, outwrestle the athlete, and crush the tiger.' It is a Divine hieroglyph of the demoniac power of the earth—of the entire earthly nature. As the bird is the clothed power of the air, so this is the clothed power of the dust; as the bird is the symbol of the spirit of life, so this of the grasp and sting of death."[1]

This well-known and eloquent passage is not absolutely accurate—thus the serpent breathes not scarcely but strongly with its one lung—but it is full of true insight into the nature of serpents, and it is an appreciation of beauty in types which most people regard with prejudice.

A few snakes have mouths which do not distend, skull bones which are slightly movable, teeth in one jaw (upper or lower) only, and rudiments of hind legs. These are included in the genera *Typhlops* and *Anomalepsis*, and are small simple ophidians.

Many are likewise non-venomous snakes, but with wider gape and more mobile skull bones, and with simple teeth on both jaws. Some are very large and have great powers of strangling. Such are the Pythons, the Boa, and the Anaconda. To these the grass snake (*Tropidonotus natrix*) is allied.

Many poisonous snakes have large permanently erect grooved fangs in the upper jaw, and a salivary gland whose secretion is venomous. Such are the cobra (*Naja tripudians*), the Egyptian asp (*Naja haje*), the coral snakes (*Elaps*), and the sea snakes (*Hydrophis*).

Other poisonous snakes have perforated fang teeth, which can be raised and depressed. Such are the vipers (*Vipera*), the British adder (*Pelias berus*), the copperhead (*Ancistrodon contortrix*), the rattlesnakes (*Crotalus*).

Tortoises and Turtles (Chelonia).—Boxed in by a bony shield above and by a bony shield below, and often with partially retractile head and tail and legs, the Chelonians are thoroughly armoured. On the average the pitch of their life is low, but their tenacity of life is great. Slow in growth, slow in movement, slow even in reproduction are many of them, and they can endure long fasting.

[1] Ruskin's *Queen of the Air*.

It is said that a tortoise walked at least 200 yards, twenty-four hours after it was decapitated, while it is well known that the heart of a tortoise will beat for two or three days after it has been isolated from the animal. In connection with their sluggishness it is significant that the ribs which help to some extent in the respiratory movements of higher animals are soldered into the dorsal shield, thus sluggish respiration may be in part the cause, as it is in part the result, of constitutional passivity. All the Chelonians lay eggs in nests scooped in the earth or sand.

The marine turtles (*e.g. Sphargis*, *Chelone*), the estuarine soft-shelled turtles (*e.g. Aspidonectes*), the freshwater turtles (*e.g. Emys*), and the snapping turtle (*Chelydra*) are more active than the land tortoises, such as the European *Testudo græca*, often kept as a pet. The tortoise of the Galapagos Islands (*Testudo elephantopus*), the river tortoise (*Podocnemys expansa*) of the Amazon, the bearded South American turtle (*Chelys matamata*), and the green turtle (*Chelone mydas*) attain a large size, sometimes measuring about 3 feet in length.

Crocodilians (Crocodilia).—Crocodiles, alligators, and gavials seem in our present perspective very much alike—strong, large, heavily armoured reptiles, at home in tropical rivers, but clumsy and stiff-necked on land, feeding on fishes and small mammals, growing slowly and without that definite limit which punctuates the life-history of most animals, attaining, moreover, a great age, freed after youth is past from the attacks of almost every foe but man. The teeth are firmly implanted in sockets; the limbs and tail are suited for swimming, and also for crawling; the heart is more highly developed than in other reptiles, having four instead of three chambers. The animals lie in wait for victims, and usually drown them, being themselves able to breathe while the mouth is full of water, if only the nostrils be kept above the surface.

8. **Birds.**—What mammals are to the earth, and fishes to the sea, birds are to the air. They are at the climax of activity, as may be inferred from their high temperature, from 2°–14° Fahrenheit higher than that of mammals.

In many other ways they rank high, for whether we consider the muscles which move the wings in flight, the skeleton which so marvellously combines strength with lightness, the breathing powers perfected and economised by a set of balloons around the lungs, or the heart which drives and receives the warm blood, we recognise that birds share with mammals the position of the highest animals. And while it is true that the brains of birds are not wrinkled with thought like those of mammals,

FIG. 92.—THE COLLOCALIA, WHICH FROM THE SECRETED JUICE OF ITS SALIVARY GLANDS BUILDS THE EDIBLE-BIRD'S-NEST.

(Adapted from Brehm.)

and that the connection between mother and unborn young characteristic of most mammals is absent in birds, it may be urged by those who know their joyousness that birds feel more if they think less, while the patience and solicitude connected with nest-making and brooding testify to the strength of their parental love. Usually living in varied and beautiful surroundings, birds have keen eyes and sharp ears, tutored to a sense of beauty, as we may surely conclude from their cradles and love

songs. They love much and joyously, and live a life remarkably free and restless, qualities symbolised by the voice of the air in their throat, and by the sunshine of their plumes. There is more than zoological truth in saying that in the bird

FIG. 93.—ONE OF THE WING-FEATHERS OF A GOLDEN EAGLE; THE VENTRAL SURFACE IS SHOWN.

The student should carefully verify all the points and study other kinds of feathers, *e.g.* down.

The axis of the feather consists of a hollow cylindrical calamus (*C*) or quill, and of a solid, rather quadrangular rachis (*R*) which carries the barbs composing the vane. The barbs are linked together by visible barbules and by microscopic barbicels. The dorsal surface of the rachis is convex; the ventral surface has a groove.

As long as the feather is growing, blood enters by a minute hole (*IU*)—the inferior umbilicus—at the base of the quill. The base is embedded in a pit or feather follicle in the skin.

At the upper end of the quill there is an unimportant slit (*SU*)—called the superior umbilicus, and near this there is a tuft of barbs, called the aftershaft (*AS*). In some birds, such as the emu, the after shaft is as long as the shaft.

"the breath or spirit is more full than in any other creature, and the earth power least," or in thinking of birds as the purest embodiments of Athene of the air.

But just as there are among mammals feverish bats with the power of true flight, and whales somewhat

fish-like, so there are exceptional birds, runners like the ostriches and cassowaries, swimmers like the penguins. Very remarkable too are some of the cuckoos and cow-birds in which the maternal instincts are largely in abeyance. As we go back into the past, strange extinct forms are discovered, with teeth and other characteristics which link the birds of the air to the reptiles of the earth. Even to-day there lives a "reptilian-bird"—*Opisthocomus*—which has retained, more than any other, indisputable affinities with the reptiles. Professor W. K. Parker, one of the profoundest of all students of birds, described this form in one of his last papers, and there used a comparison which helps us to appreciate birds. They are among backboned animals what insects are among the backboneless—winged possessors of the air, and just as many insects pass through a caterpillar and chrysalis stage before reaching the acme of their life as a flying imago, so within the veil of the eggshell and the embryonic membranes does the developing bird pass through stages somewhat like those of the developing reptile, and only gradually put on its distinctively avian characters.

The great majority of birds are fliers, and possess a keeled breast-bone, to which are fixed the muscles used in flight. To this keel or carina they owe their name Carinatæ. The flying host includes the gulls and grebes, the plovers and cranes, the ducks and geese, the storks and herons, the pelicans and cormorants, the partridges and pheasants, the sand grouse, the pigeons, the birds of prey, the parrots, the pies, and about 6,000 Passerine or sparrow-like birds, including thrushes and warblers, wrens and swallows, finches and crows, starlings and birds of paradise.

Distinct from the keeled fliers, both ancient and modern, are the running-birds, which are incapable of flight, and therefore possess a flat raft-like breast bone, to which they owe their title Ratitæ. Nowadays these are few in number, the Ostrich and the Rhea, the Cassowary and Emu, and the small Kiwi. Beside these must be ranked the giant Moa of New Zealand, not long extinct, and the more ancient, not less gigantic *Æpyornis* of Madagascar.

Fig. 94.—Decorative Male and Less Adorned Female of Spathura
—a Genus of Humming-Birds.

(From Darwin, after Brehm.)

There are many reasons for thinking that the Ratitæ do not form a natural group.

The most reptilian, least bird-like of birds is the oldest fossil of all, placed in a sub-class by itself, the *Archæopteryx* (lit. ancient bird) from strata of Jurassic age.

FIG. 95.—RESTORATION OF THE EXTINCT MOA (*Dinornis ingens*), AND ALONGSIDE OF IT THE LITTLE KIWI (*Apteryx mantelli*).
(From Chambers's *Encyclop.*; after F. v. Hochstetter.)

9. **Mammalia**.—On a quite different line of evolution from birds, and usually excelling them in brains, mammals are typically terrestrial, four-footed, and hairy. Bats and whales, seals and sea-cows, are obviously exceptional. The brain of mammals is more highly developed than that of other animals, and in the great majority there is a prolonged (placental) connection between the unborn young and the mother. In all cases the mothers feed the tender young with milk.

In the class there are three grades :—

(1) In the Duckmole (*Ornithorhynchus*), the Porcupine Ant-eater (*Echidna*), and another genus *Proechidna*, the females lay eggs. In many other ways these exclusively Australasian mammals are primitive, exhibiting affinities with reptiles.

(2) In the Marsupials, which, with the exception of the American Opossums and Selvas, are also Australasian, the young are born at a very tender age, as it were, prematurely. Only in one genus (*Perameles*) is there a true placenta as in the higher mammals. In the great majority, the mothers put the newborn young into an external pouch, where they are fed and sheltered till able

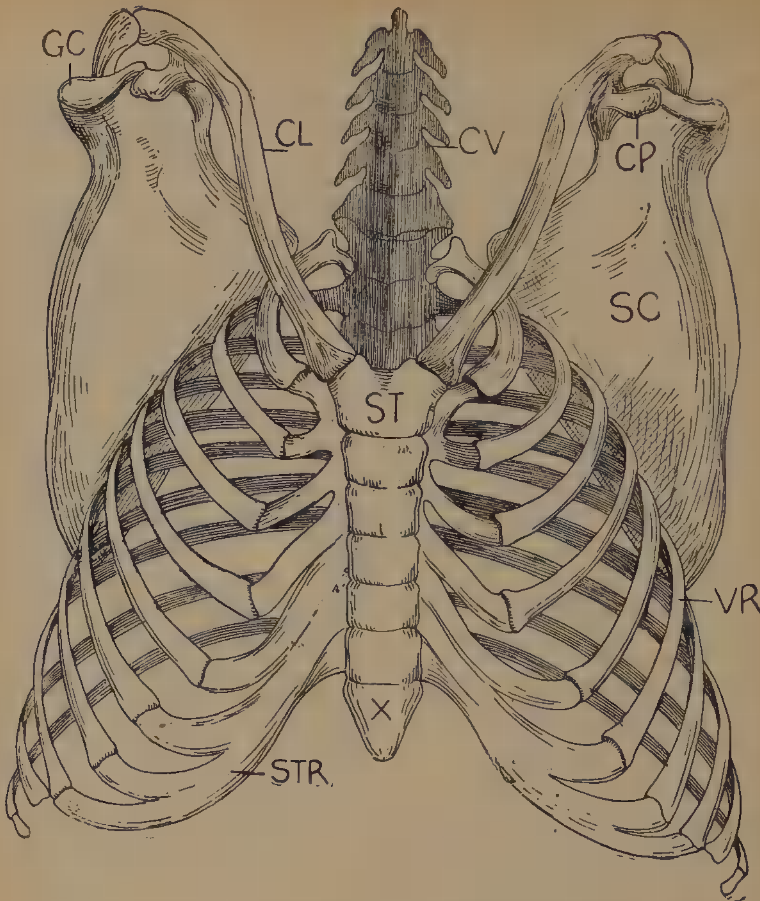


FIG. 96.—AN APE'S PECTORAL GIRDLE AND ASSOCIATED PARTS.

This characteristic part of a mammal's skeleton should be contrasted with the corresponding parts in a bird (fig. 59).

In the background are seen five of the seven neck vertebræ or cervical vertebræ (*CV*). Hiding the thoracic or dorsal region of the backbone is the segmented breastbone or sternum (*ST*), ending in a piece called the xiphisternum (*X*).

The two heads of the first rib are seen, the shorter tubercle and the longer capitulum, articulating respectively with the transverse process of the first thoracic vertebra and with the centra of the first and second. The upper part of a rib (*VR*) is called the vertebral part; the lower part (*STR*), which is cartilaginous in mammals (bony in birds), is called the sternal part.

Away behind are the broad scapulæ, or shoulder-blades. In all mammals except the oviparous Monotremes, the coracoids (so strong in birds) are mere processes of the scapula (*CP*), separate in the young embryo, fused on early in development. They share, however, in forming the glenoid cavity (*GC*) in which the head of the humerus works. The strong clavicles, or collar-bones (*CL*), are seen coming down to the top of the breast-bone.

to fend for themselves. In Australia the Marsupials have been saved by insulation from stronger mammals, which seem to have exterminated them in most other parts of the earth, for the fossils show that the race had once a much wider distribution. In their Australian retreat, apart from all higher Mammalia (mice, rabbits, and the like being modern imports), the Marsupials have evolved along many lines, prophetic of the higher orders of mammals. There are " carnivores " like the Thylacine and the Dasyure, " herbivores " like the Kangaroos, " insectivores " like the banded ant-eater *Myrmecobius*,

FIG. 97.—*Phenacodus primævus*, A PRIMITIVE EXTINCT UNGULATE FROM THE LOWER EOCENE OF NORTH AMERICA.

The actual size of the slab of rock on which it rested was 49 inches in length.

(From Chambers's *Encyclop.*; after Cope.)

" rodents " like the Wombat, and the quaint " mole-like " Notoryctes.

(3) In all the other orders of mammals there is a placental connection between mother and unborn off-spring.

Distinctly separate from all the others are the Edentates (probably several orders), represented by sloths, ant-eaters, armadillos, pangolins, and the aard-vark; and the Sirenia or Sea-cows which now include only the dugong and the manatee.

Along one fairly definite line we may rank three other orders—the Insectivores, the Bats, and the Carnivores.

The hedgehog, which is at once a lowly and a central type of mammal, may be taken as the beginning of this line. Along with shrews, moles, and the like, the hedgehogs form the order Insectivora. To these the Bats (Cheiroptera), with their bird-like powers of flight, are linked, while the Carnivora (cats, dogs, bears, and seals), though progressive in a different direction, seem also related.

Comparable to the Insectivores, but on a different line, are the gnawing Rodents, rabbits and hares, rats and mice, squirrels and beavers. This line leads on to the Elephants, from the company of which the mammoths have disappeared since man arose on the earth. With the Elephants, the rock-coneys or Hyraxes—"a feeble folk"—seem to be allied. Both are often included in the great order of hoofed animals or Ungulates, along with the odd-toed animals—horse, rhinoceros, and tapir, and a larger number of even-toed forms, hog and hippopotamus, camel and dromedary, and the true cud-chewers or ruminants such as sheep and cattle, deer and antelopes. The ancestry of the Cetaceans (Whalebone Whales, Sperm Whale, Dolphins, Porpoises, etc.) remains quite uncertain.

Fig. 98.—Head of Gorilla. (From Du Chaillu.)

A third line, which we may call median, leads through the Lemurs on to Monkeys. It must be noted, however,

that these lines, which seem distinct from one another if we confine our attention to living mammals, are linked by extinct forms.

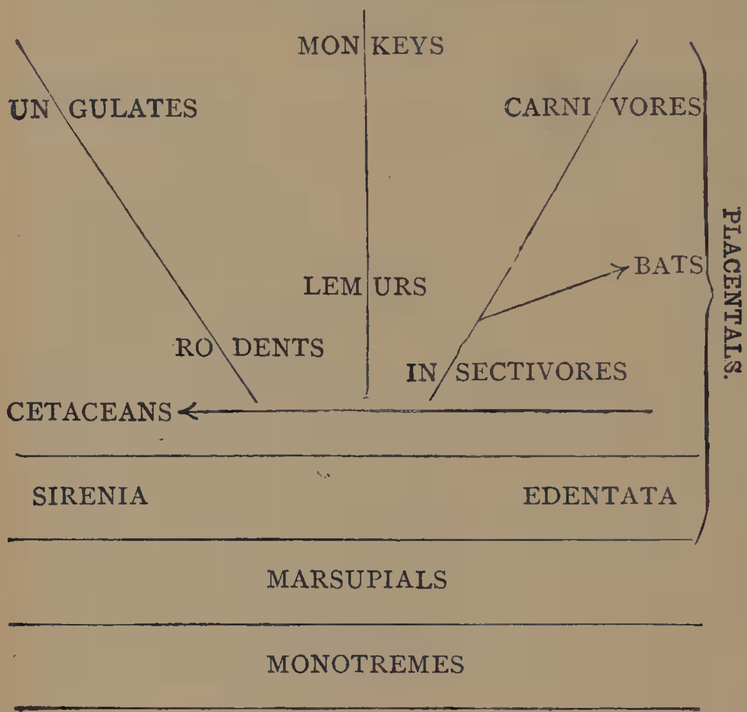
The monkeys which come nearest to man in structure, habits, and intelligence, are the anthropoid apes—the gorilla, the chimpanzee, the orang-utan, and the gibbon. The last is at a much greater distance than the three others. A second grade is represented by the more dog-like, narrow-nosed Old World apes, such as the baboons and mandrills. Lower in many ways are the broad-nosed New World or American monkeys, *e.g.* the numerous species of *Cebus*, while lowest and smallest among true monkeys are the South American marmosets. Distinct from all these, and outside the monkey order altogether, are the so-called half-monkeys or Lemurs.

FIG. 99.—HEAD OF MALE SEMNOPITHECUS. (From Darwin.)

We might describe the clever activities of monkeys, the shelters which some of them make, their family life, parental care and sociality, their docility, their intelligent habits of investigation, and their quickness to profit by experience; but it would all amount to this, that their life at many points touches the human, that they are in some ways like growing children, in other ways

like savage men, though with more circumscribed limits of progress than either.

CHIEF ORDERS OF MAMMALS



SURVEY OF THE ANIMAL KINGDOM

VERTEBRATES.

BIRDS.
Flying-Birds. Running-Birds.
Archæopteryx.

MAMMALS. Placentals.
Marsupials.
Monotremes.

Snakes. Lizards. REPTILES. Crocodiles. Tortoises.
Sphenodon.

FISHES. Bony Fishes.
Double-Breathers.
Elasmobranchs.

AMPHIBIANS.
Newt. Frog.
Cæcilian.

CYCLOSTOMES.
Lamprey. Hagfish.

LANCELETS.

TUNICATES.

CŒLOMATES.

INVERTEBRATES.

Insects. Arachnids.
Myriapods.
Peripatus.
ARTHROPODS.
Crustaceans.

ENTEROPNEUSTS.

ANNELIDS.
" WORMS."
THREAD WORMS.
FLAT-WORMS.

Cuttlefish.
Gasteropods.
MOLLUSCS.
Bivalves.

Feather-stars.
Brittle-stars.
Starfish.
ECHINODERMS.
Sea-urchins.
Sea-cucumbers.

METAZOA.

Ctenophores. Jellyfish. Sea-anemones and Corals.
STINGING-ANIMALS or CŒLENTERATES.
Medusoids and Hydroids.

SPONGES.

Infusorians. Rhizopods. Sporozoa.
SIMPLEST ANIMALS.

PROTOZOA.

PART III

DEVELOPMENT AND LIFE-HISTORIES

CHAPTER XIV

THE CONTINUANCE OF LIFE

1. Modes of reproduction—2. The evolution of sex—3. Divergent modes of reproduction—4. Historical—5. The egg-cell or ovum—6. The male-cell or spermatozoon—7. Maturation—8. Fertilisation.

In his exercitation "on the efficient cause of the chicken," Harvey (1651) confesses that "although it be a known thing subscribed by all, that the fœtus assumes its original and birth from the male and female, and consequently that the egge is produced by the cock and henne, and the chicken out of the egge, yet neither the schools of physicians nor Aristotle's discerning brain have disclosed the manner how the cock and his seed doth mint and coine the chicken out of the egge." The marvellous facts of development are familiar—the sprouting corn and the opening flowers, the growth of the chick within the egg and of the child within the womb; yet so difficult is the task of inquiring wisely into this marvellous renewal of life that we must reiterate the old confession: "ingratissimum opus scribere ab iis quæ, multis a natura circumjectis tenebris velata, sensuum lucis inaccessa, hominum agitantur opinionibus."

1. **Modes of Reproduction.**—The simplest animals divide into two or into many parts, each of which becomes a full-grown Protozoon. There is no difficulty in under-

standing why each part should be able to regrow the whole, for each is a fair sample of the original unity. Indeed, when a large Protozoon is cut into two or three pieces with a knife, each piece, if nucleated, may retain the movements and life of the intact organism. Among the Protozoa we find some in which the multiplication looks like the rupture of a cell which has become too large; in others numerous buds are set free from the surface; in others one definitely-formed bud (like an overflow of the living matter) is set free; in others the cell divides into two equal parts, after the manner of most cells; and numerous divisions may also occur in rapid succession and within a cyst, that is, in limited time and space, with the result that many "spores" are formed. These modes of multiplication form a natural series.

In the many-celled animals multiplication may still proceed by the separation of parts; indeed the essence of reproduction always is the separation of part of an organism to form—or to help to form—a new life. Sponges bud profusely, and small buds are sometimes set adrift; the *Hydra* forms daughter polypes by budding, and these are set free; sea-anemones and several worms, and even some starfishes, multiply by the separation of comparatively large pieces. But this mode of multiplication—which is called asexual—has evident limitations. It is an expensive way of multiplying. It is possible only among comparatively simple animals in which there is no very high degree of differentiation and integration. For though cut-off pieces of a sponge, *Hydra*, sea-anemone, or simple worm may grow into adult animals, this is obviously not the case with a lobster, a snail, or a fish. Thus with the exception of the degenerate Tunicates there is no budding among Vertebrates, nor among Molluscs, nor among Arthropods.

The asexual process of liberating more or less large parts, being expensive, and possible only in simpler animals, is always either replaced or accompanied by another method—that of sexual reproduction. The phrase "sexual reproduction" covers several distinct facts: (*a*) the separation of special reproductive cells;

(*b*) the production of two different kinds of reproductive cells (spermatozoa and ova), which are dependent on one another, for in most cases an ovum comes to nothing unless it be united with a male-cell or spermatozoon, and in all cases the spermatozoon comes to nothing unless it be united with an ovum; and (*c*) the production of spermatozoa and ova by different (male and female) organs or individuals.

(*a*) It is easy to think of simple many-celled animals being multiplied by liberated reproductive cells, which differed but little from those of the body. But as more and more division of labour was established in the bodies of animals, the distinctness of the reproductive cells from the other units of the body became greater. Finally, the prevalent state was reached, in which the only cells able to begin a new life when liberated are the reproductive cells or germ-cells. They owe this power to the fact that they have not shared in making the body, but have preserved intact the characters of the fertilised ovum from which the parent itself arose.

(*b*) But, in the second place, it is easy to conceive of a simple multicellular animal whose liberated reproductive cells were each and all alike able to grow into new organisms. In such a case, we might speak of sexual reproduction in one sense, for the process would be different from the asexual method of liberating more or less large parts. But yet there would be no fertilisation and no sex, for fertilisation means the union of mutually dependent reproductive cells, and sex means the existence of two physiologically different kinds of individuals, or at least of organs producing different kinds of reproductive cells. We can infer from the Protozoa how fertilisation or the union of the two kinds of reproductive cells may have had a gradual origin. For in some of the simplest Protozoa, *e.g.* *Protomyxa*, a large number of similar cells sometimes flow together; in a few cases three or more combine; in most a couple of apparently similar units unite; while in a few instances, *e.g.* *Vorticella*, a small cell fuses with a large one, just as a spermatozoon unites with an ovum.

(*c*) But the higher forms of sexual reproduction imply more than the liberation of special reproductive cells, more than the union of two different and mutually dependent kinds of reproductive cells,—they imply the separation of the sexes. It is unnecessary to complicate the problem by considering just at present the frequent occurrence of hermaphroditism, *e.g.* in earthworm and snail, where the production of male and female germ-cells is combined in one animal. The main problem is the evolution of male and female individuals, *i.e.* fundamentally, of sperm-producers and egg-producers.

2. The Evolution of Sex.—If we study those interesting Infusorian colonies, of which *Volvox* is a good type, the riddle may be at least partially read. Though Protozoa, they are balls of cells, in which the component units are united by protoplasmic bridges and show almost no division of labour. In some colonies there is asexual multiplication, for certain cells divide up into clusters of cells which escape from the parent and form new free-swimming balls. In other conditions a less direct multiplication occurs. Some of the cells—apparently better fed than their neighbours—become large; others, less successful, divide into many minute units each with two flagella. The large kind of cell is fertilised by the small kind of cell (from another colony), and there is no reason why we should not call them ova and spermatozoa respectively. In some colonies both kinds of reproductive cell are formed, in others only ova; in others only spermatozoa. There may be hermaphroditism, or sometimes the colony is almost quite female, or almost quite male. In some cases the ova develop parthenogenetically, without being fertilised. Indeed we have in *Volvox*, as Dr. Klein—an enthusiastic investigator of this form—rightly says, an epitome of all the great steps in the evolution of sex.

So far we have stated facts; let us now briefly state a theory[1] which seeks to unify them.

All through the animal series, from the active In-

[1] *The Evolution of Sex,* by Patrick Geddes and J. Arthur Thomson, 1889. Revised Ed. 1901.

fusorians and passive Gregarines, to the feverish birds and sluggish reptiles, and down into the detailed contrasts between order and order, species and species, an antithesis may be read between predominant activity and preponderant passivity, between lavish expenditure of energy and a habit of storing, between a relatively more disruptive (*katabolic*) and a relatively more constructive (*anabolic*) series of changes in the protoplasmic life of the creature. The contrast between the sexes is an expression of this fundamental alternative of variation.

The theory is confirmed by contrasting the characteristic product of female life—passive ova, with the characteristic product of male life—active spermatozoa; or by summing up the complex conditions (abundant food, favourable temperature, and the like) which sometimes favour the production of female offspring, with the opposite conditions which sometimes favour maleness.

The thesis of *The Evolution of Sex* (Geddes and Thomson, 1889) was that males and females differ in the nature and intensity of their metabolism. They live at different physiological rates, the expenditure of the male, or the ratio of katabolism to anabolism, being relatively greater than in the female. This view is in part confirmed by the important experimental work of Geoffrey Smith, who has shown how the parasitic Crustacean Sacculina alters the metabolism of the male crab and induces the production of ova and the putting on of feminine characters. "This adaptive regulation," he says, "consists in the production of at least a partially female condition of metabolism as opposed to a wholly male condition, the female condition being preponderantly anabolic or conservative, as opposed to the katabolic male condition, and by this change from a katabolic to a more anabolic condition the animal can withstand better the drain on its system increased by the parasite." Mr. Walter Heape, an accomplished embryologist, inclines to the same view. Writing in 1913, he says:

"The Male and the Female individual may be compared in various ways with the spermatozoon and ovum. The Male is active and roaming, he hunts for his partner and is an expender of energy;

the Female is passive, sedentary, one who waits for her partner and is a conserver of energy."

Perhaps the average differences between the sexes may be summed up tentatively in this tabular contrast :[1]

Male.	Female.
Sperm-producer.	Egg-producer.
Less expensive reproduction.	More expensive reproduction.
More intense metabolism.	Less intense metabolism.
Relatively more katabolic.	Relatively more anabolic.
Often with shorter life.	Often with longer life.
Often smaller.	Often larger.
Often more brilliantly coloured and more decorative.	Often quieter in colour and plainer in decoration.
Rising to more intense outbursts of energy.	Capable of more patient endurance.
More impetuous and experimental.	More persistent and conservative.
More divergent from the youthful type.	Nearer the youthful type.
Often more variable.	Often less variable.
Making more of sex-gratification.	Making more of the family.
More combative.	Consolidating the family.

Apart from the general problem of the evolution of sex, those who find the subject interesting should think about the evolution of the so-called "sexual instincts," as illustrated in the attraction of mate to mate. One of the outstanding facts is that the stimulus of proximity and contact, which is alone apparent in the lower reaches of the animal kingdom, comes to be associated, as we ascend the scale, with all manner of subtle æsthetic attractions. In this study of what has been one of the great dynamics of evolution, we all do well to remember with Thoreau, that "for him to whom sex is impure, there are no flowers in nature."

3. Divergent Modes of Reproduction.—(*a*) *Hermaphroditism.*—Especially among lower animals, both ova and spermatozoa may be produced by one individual, which

[1] From *Sex*, by Geddes and Thomson, Home University Library, 1914.

is then said to be hermaphrodite. Some sponges and stinging animals, many "worms," e.g. earthworm and leech, barnacles and acorn-shells among Crustaceans, one of the edible oysters, the snail, and many other Molluscs, the sea-squirts, and the hagfish, are all hermaphrodite. But it should be noted that the organs in which ova and spermatozoa are produced are in most cases separate, that the two kinds of cells are usually formed at different times, and that the fertilisation of ova by spermatozoa from the same animal (*e.g.* in liver-fluke) is very rare. In some cases hermaphroditism may have arisen as a secondary complication, derived from, not antecedent to, the ordinary (diœcious) condition. In other cases a hermaphrodite state of periodic maleness and femaleness may be primitive. Except in Tunicates, a few fishes and amphibians, and casual abnormalities, hermaphroditism does not occur among the backboned animals.

(*b*) *Parthenogenesis* seems to be a specialised form of sexual reproduction in which the ova produced by female organisms develop without being fertilised by male cells. Thus "the drones have a mother but no father," for they develop from ova which are not fertilised. In some rotifers the males have never been found, and yet the fertility of the females is very great; in many small crustaceans ("water-fleas") the males seem to die off and are unrepresented for long periods; in the aphides males may be absent all the summer (or in a greenhouse for years) without affecting the rapid succession of female generations.

In a few multicellular animals there is a kind of multiplication by spore-cells, which require no fertilisation but are hardly to be regarded as on the level of egg-cells. They are well-illustrated by the cells in the sporocyst of the liver-fluke (p. 235) which give rise to rediæ, or to the cells in the rediæ which give rise to more rediæ or to cercariæ. Perhaps these spore-cells represent a harking-back to a very primitive mode of multiplication by means of germ-cells which were not as yet differentiated as sex-cells.

(*c*) *Alternation of Generations.*—A fixed asexual zoo-

phyte or hydroid sometimes buds off and liberates sexual swimming bells or medusoids, whose fertilised ova develop into embryos which settle down and grow into hydroids. This is perhaps the simplest and clearest illustration of alternation of generations—the alternate occurrence in one life-history of two (or more) different forms differently produced.

In autumn the freshwater sponge (*Spongilla*) begins to suffer from the cold and the scarcity of food. It dies away; but some of the cells become compacted together to form "gemmules" from which in spring male and female sponges are developed. The males are short-lived, but their spermatozoa fertilise the ova of the females. The fertilised ovum develops into a ciliated embryo, and this into the asexual sponge, which produces the gemmules.

FIG. 100.—DIAGRAM OF A HYDROID COLONY, SOME OF THE INDIVIDUALS OF WHICH HAVE BEEN MODIFIED AS SWIMMING-BELLS OR MEDUSOIDS; ONE OF THESE HAS BEEN LIBERATED.

The large free-swimming and sexual jellyfishes of the genus *Aurelia* produce ova and spermatozoa; from the fertilised ovum an embryo develops not into a jellyfish, but into a sessile polyp-stage (the Hydra-tuba). This grows and divides transversely into a strobila or "pile-of-saucers" stage. "Saucer" after "saucer" is separated

off as a free-swimming ephyra which eventually becomes a sexual jellyfish (see fig. 65).

Similar but sometimes more complicated alternations occur in some worm-types (some flukes, threadworms, etc.), and as high up in the series as Tunicates; while among plants analogous alternations are very common, *e.g.* in the life-cycles of fern and moss.

4. **Historical.** In the seventeenth and eighteenth centuries, naturalists had a short and easy method of dealing with embryology. They maintained that within the seed of a plant, within the egg of a bird, the future organism was already present in miniature. Every germ contained a miniature model of the adult, which in development was simply unfolded. It was to this unfolding that the word evolution (as a biological term) was first applied. But not only did they compare the germ to a complex bud hiding the already formed organs within its hull, they maintained that it included also the next generation and the next and the next. Some said that the ovum was most important, that it required only the sperm's awakening touch and it began to unfold; others said that the animalcules or spermatozoa produced by male animals were most important, that they only required to be nourished by the ova. The two schools nicknamed one another "ovists" and "animalculists." The preformation-theories were false, as Harvey in the middle of the seventeenth century discerned, and as Wolff a century later proved, because germs are demonstrably simple, and because embryos grow gradually part by part. But in a later chapter we shall see that the theories were also strangely true.

5. **The Egg-cell or Ovum** produced by a female animal, or at least by a female organ (ovary), exhibits the usual characteristics of a cell. It often begins like an Amœba, and may absorb adjacent cells; in most cases it becomes surrounded by an envelope or by several sheaths; in many cases it is richly laden with yolk derived from various sources. In the egg of a fowl, the most important part (out of which the embryo is made) is a small area of transparent living matter which

lies on the top of the yellow yolk and has a nucleus for its centre ; round about there is a coating of white-of-egg ; this is surrounded by a double membrane which forms an air-chamber at the broad end of the egg ; outermost is the porous shell of lime.

The cell-substance of the ovum, when it is not encumbered or disguised with a large or relatively large quantity of yolk, sometimes shows an intricate protoplasmic structure. Of great interest is the occasionally demonstrable presence of definite formed bodies (mitochondria, etc.) in the protoplasm, which in some instances have been proved to be "organ-forming substances." For if they are carefully removed, the embryo is lacking in certain parts. Within the nucleus (or germinal vesicle) of the ovum there are readily stainable chromatin-elements or chromosomes,—always definite in number.

Eggs differ greatly in regard to the amount of yolk which they contain ; thus those of birds and reptiles have much, while those of all mammals except the old-fashioned Monotremes have hardly any. This is related partly to the number of eggs which are produced, and partly to the amount of food-capital which the embryo requires before other sources of supply become available. The young of birds and reptiles feed on the yolk until they are hatched, the unborn young of all the higher (placental) mammals absorb food from the mother. The different sizes of egg usually depend upon the amount of yolk, for the really vital portion out of which the embryo is made is always very small.

There are many differences also in regard to the outer envelopes, witness the jelly around the spawn of frogs, the firm but delicate skin around the ova of cuttlefish, the horny mermaid's-purse enclosing the skate's egg, the chitinous sheath surrounding the ova of many insects, the calcareous shell in birds and most reptiles.

6. **The Male-Cell or Spermatozoon** produced from a male animal, or at least from a male organ (testis), is very different from the ovum. It is very minute and very active. If we compare an ovum to an Amœba or to an encysted Gregarine among Protozoa, we may liken the

spermatozoon to a minute monad Infusorian. It is a very small cell, bearing at one end a "head," which consists mostly of nucleus, prolonged at the other end into a mobile "tail," which lashes the head along (fig. 102).

Between the "head" of the spermatozoon and the "tail" there is a little connecting piece, or "middle piece," and in this lies a minute body the centrosome,

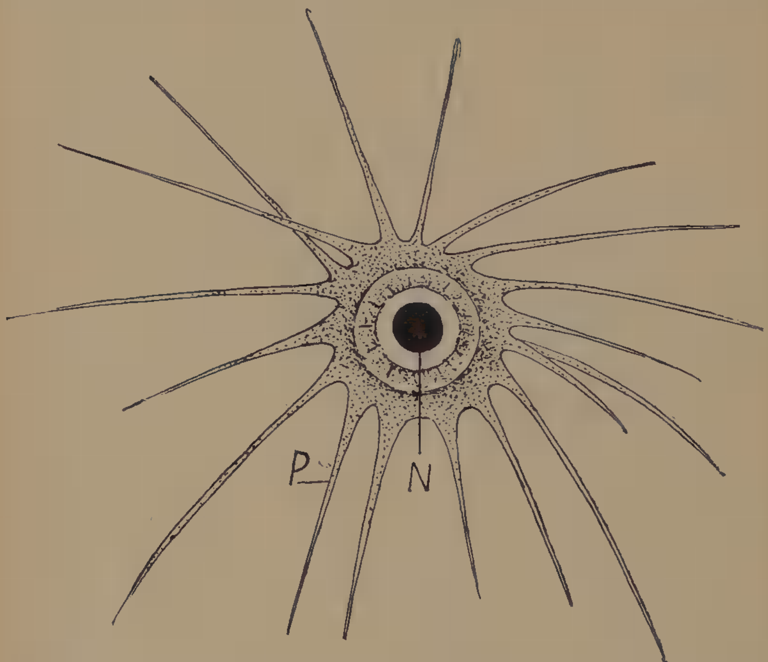


FIG. 101.—THE MALE-CELL OR SPERMATOZOON OF A CRAYFISH.

In most Crustaceans the spermatozoa are sluggish and give off radiating locomotor processes (*P*). They are quite unlike typical spermatozoa which have a small head containing the nucleus and a relatively long locomotor tail. In most Crustaceans, as in the crayfish, lobster, and crab, the spermatozoa are deposited upon the eggs. The nucleus (*N*) is seen surrounded by more cytoplasm than is usual in a spermatozoon.

which is introduced by the spermatozoon into the egg and plays an important part in the divisions which follow fertilisation.

In the history of the spermatozoa within the testis, a number of primitive sperm-cells (spermatogonia), which should be compared to the primitive egg-cells

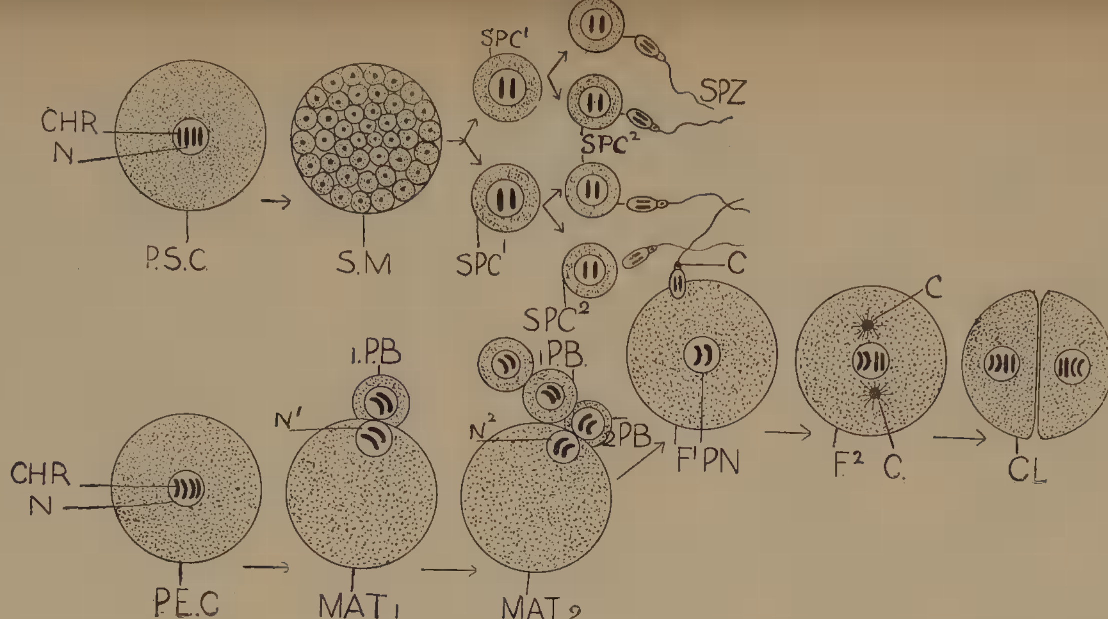


FIG. 102.—MATURATION AND FERTILISATION.

The upper line shows the formation and maturation of spermatozoa. The lower line shows the maturation of the ovum. The middle line shows fertilisation and the first cleavage (*CL*).

P.S.C. a primitive sperm-cell; *N*, its nucleus, with four chromosomes (*CHR*), which have been drawn straight. It divides into a ball of cells or sperm-morula (*S.M.*), giving rise to spermatocytes (*SPC*1) which show only two chromosomes, a reduction or meiotic division having occurred. These divide again into spermatocytes (*SPC*2), which are differentiated into spermatozoa (*SPZ*), each with two chromosomes, a centrosome (*C*), and a tail.

P.E.C., a primitive egg-shell, *N* its nucleus, with four chromosomes (*CHR*), drawn curved. *MAT*1 shows the first maturation division, a reduction or meiotic division, for the first Polar Body (1*P.B.*) goes off with two chromosomes. It may divide again as in *MAT*2. The second Polar Body (2*P.B.*) is formed by an ordinary equation division. N^2 is the female pro-nucleus, the reduced nucleus of the ripe ovum. It is the same as *PN* in the next figure (F^1).

F^1, the spermatozoon enters the ovum. F^2, fertilisation has been accomplished. The nucleus, it will be seen, has two paternal and two maternal chromosomes. The centrosome (*C*) introduced by the spermatozoon has divided into two.

CL., the fertilised ovum divides into two daughter cells or blastomeres. Each has a nucleus with two paternal chromosomes, drawn straight, and two maternal chromosomes, drawn curved.

(oogonia), divide and redivide, often forming balls of cells. They give rise to spermatocytes, which also multiply by division. The last chapter in the spermatogenesis is the transformation of spermatocytes into spermatozoa.

In some cases spermatozoa which have been transferred to a female may lie long dormant there. Thus those received by the queen-bee during her nuptial flight may last for a whole season, or even for three seasons, during which they are used in fertilising those ova which develop into workers or queen-bees.

7. **Maturation of the Ovum.**—Before an egg-cell is fertilised it usually exhibits a remarkable process of maturation. The nucleus moves to the surface and divides twice in rapid succession, forming two minute cells or polar bodies, which are extruded and come to nothing. The first of these two divisions is usually quite unique, for by it the number of chromosomes is reduced to half the normal number, whereas in ordinary nuclear division each chromosome is cleft longitudinally and the number remains the same. In the formation of the spermatozoa there is a similar reducing or meiotic division, and thus when the spermatozoon and ovum unite in fertilisation, the normal number of chromosomes is restored. The reduction of the chromosomes by a half is probably of great importance in connection with variation and heredity. It enables us to understand how certain items in the inheritance may drop out altogether, or how they may be represented only in a certain proportion of the offspring.

8. **Fertilisation.**—When a pollen grain is carried by an insect or by the wind to the stigma of a flower, it grows down through the tissue of the pistil until it reaches the ovule and the egg-cell which that contains. Then a nuclear element belonging to the pollen cell unites with the nucleus of the egg-cell. The union is intimate and complete.

When spermatozoa come in contact with the egg-shell of a cockroach ovum, they move round and round it in varying orbits until one finds entrance through a minute

aperture in the shell. It works its way inwards until its nuclear part unites with that of the ovum. The union is again intimate and complete.

The result of fertilisation is the intimate and orderly union of the nucleus of the egg-cell and the nucleus of the sperm-cell, but it must be remembered that there is also a mingling of the infinitesimally minute cell-substance or cytoplasm of the spermatozoon with the relatively large cell-substance of the ovum. Some idea both of the orderly complexity of the nuclear union and of the carefulness of modern investigation may be gained from the fact that the nucleus of each of the two daughter-cells which result from the first division of the fertilised egg-cell is made up of chromatin contributions half maternal and half paternal. This equal partition has been followed for a number of successive divisions, the actual demonstration of this being rendered possible in some cases by a visible difference between the maternal and paternal chromosomes.

Five chief things happen when an animal ovum is fertilised by a sperm. (1) There is a mingling of two inheritances,—of the maternal and paternal germ-plasms. (2) There is a restoration of the number of chromosomes to the normal. As the ripe ovum has had its number reduced to one half of the normal, and as the same is true of the ripe spermatozoon, the union of the two must bring back the normal number, which is usually adhered to in all the cells of the offspring. (3) The spermatozoon brings into the ovum a minute body known as the centrosome, which plays an important part in the subsequent division or segmentation. (4) When a spermatozoon enters the ovum, there is a very rapid physical change in the periphery. The ovum becomes non-receptive to other spermatozoa. The way is "blocked," and this usually prevents multiple fertilisation, which is one of the causes of abnormal development. (5) There is some stimulus to the egg to divide or the removal of some embargo which has kept the egg from dividing. A very remarkable fact, established by Loeb, Delage, and others, is that this part of fertilisation—the setting

of the egg-cell a-dividing—can be induced in many cases by a great variety of stimuli. Such a development, without the aid of a spermatozoon—is described as "artificial parthenogenesis." The stimuli may be mechanical, chemical, thermal, electrical, and they are known to work effectively in a great variety of cases,—some starfishes, sea-urchins, worms, insects, molluscs, fishes, and amphibians. It may serve to leave sea-urchin ova for a short time in sea-water with slightly altered composition and concentration, or to prick frogs' eggs with a platinum needle and wash them in blood. If development is to proceed normally—and both sea-urchins and frogs have been reared from artificially parthenogenetic ova—two steps seem to be necessary. The egg-cell must be activated (by a positive stimulus or by the removal of some obstacle to division) and there must be an immediate corrective or counteractive of this, otherwise the segmentation of the egg will simply end in disintegration.

CHAPTER XV

DEVELOPMENT

1. Segmentation and after—2. Differentiation—3. Some generalisations: (*a*) the ovum theory; (*b*) the gastræa theory; (*c*) recapitulation; (*d*) organic continuity.

1. **Segmentation and After.**—The fertilised egg-cell divides, and by repeated division and growth of cells every embryo, of herb and tree, of bird and beast, is formed. On the quantity and arrangement of the yolk the character of the segmentation in part depends, but there are other factors involved. When there is little or no yolk the whole ovum divides into equal parts, as in sponge, earthworm, starfish, lancelet, and higher mammal. When there is more than a little yolk, and when this sinks to the lower part of the egg-cell, the division is complete but unequal, and this may be readily seen by examining freshly laid frog-spawn. When the yolk is accumulated in the core of the egg-cell, the more vital superficial part divides, as in insects and many crustaceans. Lastly, when the yolk is present in large quantity as in the ova of gristly fishes, reptiles, and birds, the division is very partial, being confined to a small but rapidly extending area of formative living matter, which lies like a drop on the surface of the yolk.

As the result of continued division, a ball of cells is formed. This may be hollow (a *blastosphere*), or solid (a *morula*, *i.e.* like a mulberry), or it may be much modified in form by the presence of a large quantity of yolk. Thus in the hen's egg what is first formed is a disc of cells technically called the *blastoderm*, which gradually spreads around the yolk.

The hollow ball of cells almost always becomes dimpled in or invaginated, as an india-rubber ball with a hole in it might be pressed into a cup-like form. The dimpling is the result of inequalities of growth. The two-layered sac of cells which results is called a *gastrula*, and the cavity of this sac becomes in the adult organism the digestive part of the food-canal. Where there is no hollow ball of cells, but some other result of segmentation, the formation of a gastrula is not so obvious. Yet in most cases some analogous infolding is demonstrable.

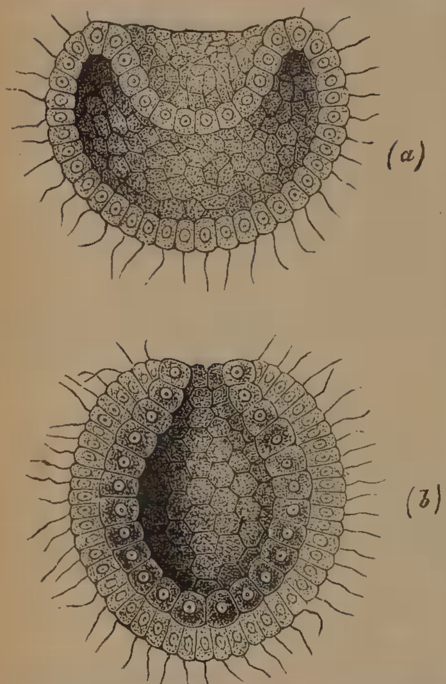


Fig. 103.—The Formation of the Two-layered Gastrula from the Invagination of a Hollow Sphere of Cells.

(From the *Evolution of Sex*; after Haeckel.)

In the hollow sac of cells there are already two layers. The outer, which is called the ectoderm or epiblast, forms in the adult the outer skin, the nervous system, and the most important parts of the sense-organs. The inner, which is called the endoderm or hypoblast, forms the lining of the most important part of the food-canal, and of such appendages as lungs, liver, and pancreas which are outgrowths from it. But in all animals above the Sponges and Cœlenterates, a middle layer appears between the other two. From this—the mesoderm or mesoblast—the muscles, the internal skeleton, the connective-tissue, etc., are formed.

2. **Differentiation.**—Development is the expression or realisation of the inheritance. It is the making visible of

the latent manifoldness of the liberated fragment, or sample, or germ-cell. It is the expliciting of what is implicit in the fertilised egg-cell, and it seems to most reflective minds one of the major wonders of the world. There are two great processes involved :—*differentiation* or the growing complexity of parts, and *integration* or the unification and harmonisation of the parts. Differentiation is like the extension of a great empire, integration means federation. Integration follows on differentiation, and is established in great part by the nervous system, aided by the common medium of the blood and the distribution of the regulative secretions or hormones of ductless glands such as the thyroid and the adrenal.

How differentiation comes about we do not as yet know. Localised differences of structure appear in the developing embryo, affecting the constitution of the colloidal physical substratum. According to Prof. Child the organism is fundamentally a specific reaction system ("a protoplasm of specific constitution with a corresponding metabolic specificity"), and differences in the rate of metabolism initiate the process of organisation, somewhat in the same way as differences in the bed of a river are determined by the rate of flow.

Weismann's view of development was that qualitatively diverse particles in the germ-plasm are sorted out in proper sequence to the various areas of the embryo, the chromosomes being the carriers and distributors of these materials. The germ-plasm was supposed to disintegrate in different ways in different body-cells. If we picture the whole inheritance as a collection of many different kinds of seeds, we may think of certain seeds being planted in certain cells and others elsewhere. But the behaviour of the chromosomes does not hint at any sorting-out procedure, and the way in which a fragment may regrow a whole is difficult to explain (without subsidiary hypotheses) on Weismann's theory of differentiation.

Prof. De Vries, Prof. T. H. Morgan, and others have argued from experimental results and microscopical observations that all the hereditary constituents or factors are present in every cell in the body. Each gets

the same "complex factorial background," and regional peculiarities of different parts of the developing embryo determine which shall find expression and which shall be latent. There is no sorting out to appropriate cells, but each receives the complete hereditary organisation. To return to our metaphor, each plot receives the whole collection of seeds, but environmental conditions of soil, temperature, position, and the like determine that only certain seeds will develop in each plot. In any case the student must realise that the most familiar of processes —differentiation—remains very mysterious.

3. **Some Generalisations.**—(*a*) *The "Ovum-Theory."* To realise that almost every organism from sponge to man begins its life as a fertilised egg-cell, and is built up by the division and arrangement, layering and folding of cells, should not lessen, but should greatly enhance, the wonder with which we look upon life. If the end of this constantly repeated process of development be something to marvel at, the same is equally true of its beginning.

(*b*) *The Gastræa Theory.* From the frequent, though not universal occurrence of the two-layered gastrula stage in the development of animals, Haeckel concluded that the first stable form of many-celled animals must have been something very like a gastrula. He called this hypothetical ancestor of all many-celled animals a *Gastræa*, and his inference has found favour with many naturalists. Some of the simplest sponges, polyps, and "worms" are hardly above the gastrula level.

(*c*) *Recapitulation.* Von Baer, one of the pioneer embryologists in the first half of the nineteenth century, discerned that the individual development is from the general to the special. He recognised that even one of the higher animals, let us say a rabbit, first puts on the features of a primitive Vertebrate, that it subsequently shows the character of an embryo fish, then of an embryonic reptile, then of an embryonic mammal, then of a young rodent, finally of a young rabbit. He confessed his inability to tell whether a number of very young embryos, freed from their surroundings, were those of reptiles, birds, or mammals. In stating Von Baer's

vivid idea of development as progress from the general to the special, we must be particularly careful to notice that he did not say that the young mammal was once like a little fish, afterwards like a reptile, and so on; he compared the embryo mammal at one stage with the

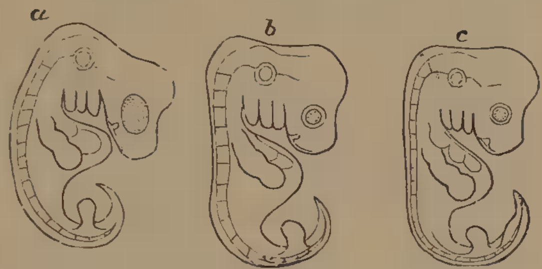


FIG. 104.—EMBRYOS OF FOWL, *a*; DOG, *b*; MAN, *c*. (From Chambers's *Encyclop.*; after Haeckel.)

embryo fish, at another stage with the embryo reptile, which is a very different matter.

Fritz Müller, in his *Facts for Darwin*, illustrated the idea of recapitulation in his studies of the life-histories of Crustacea. When a young crayfish is hatched, it is practically a miniature adult. When a young lobster is hatched, it differs not a little from the adult, and is described as being at a Mysis stage,—*Mysis* being a prawn-like crustacean. It grows and moults and becomes a little lobster. When a crab is hatched, it is quite unlike the adult, it is liker one of the humblest Crustacea such as the common water-flea *Cyclops*, and is described as a Zoæa. This Zoæa grows and moults, and becomes, not yet a crab, but a prawn-like animal with extended tail, a stage known as the Megalopa. This grows and moults, tucks in its tail, and becomes a young crab. And again, when the shrimp-like crustacean, known as *Penœus*, is hatched, it is simpler than any known crustacean, it is an unsegmented somewhat shield-shaped little creature with three pairs of appendages and a median eye. It is known as a Nauplius and resembles the larvæ of most of the lower crustaceans. It grows and moults and becomes

a Zoæa, grows and moults and becomes a Mysis, grows and moults and becomes a *Penæus* (see figs. 105 to 108).

Now, these life-histories are hardly intelligible at all unless we believe that *Penæus* does in some measure recapitulate the steps of racial progress, that the crab does so to a slighter extent, that the lobster has abbreviated its obvious recapitulation much more, while the crayfish has found out a short cut in development. Let us exercise our imagination and think of the ancestral

FIG. 105.—LIFE-HISTORY OF *Penæus*; THE NAUPLIUS.

Crustacea perhaps not much less simple than the Nauplius larvæ which many of them exhibit. In the course of time some pushed forward in evolution and attained to the level of structure represented by the Zoæa larvæ. At this station some remained and we have already mentioned the "water-flea" *Cyclops* as a crustacean which persists near this level. But others pushed on and reached a stage represented by *Mysis*, and finally the highest crustaceans were evolved.

Now to a certain extent these highest crustaceans have

to travel in their individual development along the rails laid down in the progress of the race. Thus *Penæus*, starting of course as an ovum at the unicellular level, has to stop as it were at the first distinctively crustacean station—the Nauplius stage. After some change and delay, it continues to progress, but again there is a halt and a change at the Zoæa station. Finally there is another delay at the Mysis stage before the *Penæus* reaches its destination. The crab, on the other hand, stops first at the Zoæa station, the lobster at the Mysis station, while the crayfish though progressing very gradually like all the others, has—if the simile be not too grotesque—a through-carriage all the way.

FIG. 106.—LIFE-HISTORY OF *Penæus*; THE ZOÆA.

One must be careful not to press the idea of recapitulation too far, (1) because the individual life-history tends to skip stages which occurred in the ancestral progress; (2) because the young animal may acquire new characters which are peculiar to its own near lineage and have little or no importance in connection with the general evolution of its race; (3) because, in short, the resemblance between the individual and racial history (so far as we know them) is general, not precise. Thus we regard Nauplius and Zoæa rather as adaptive larval

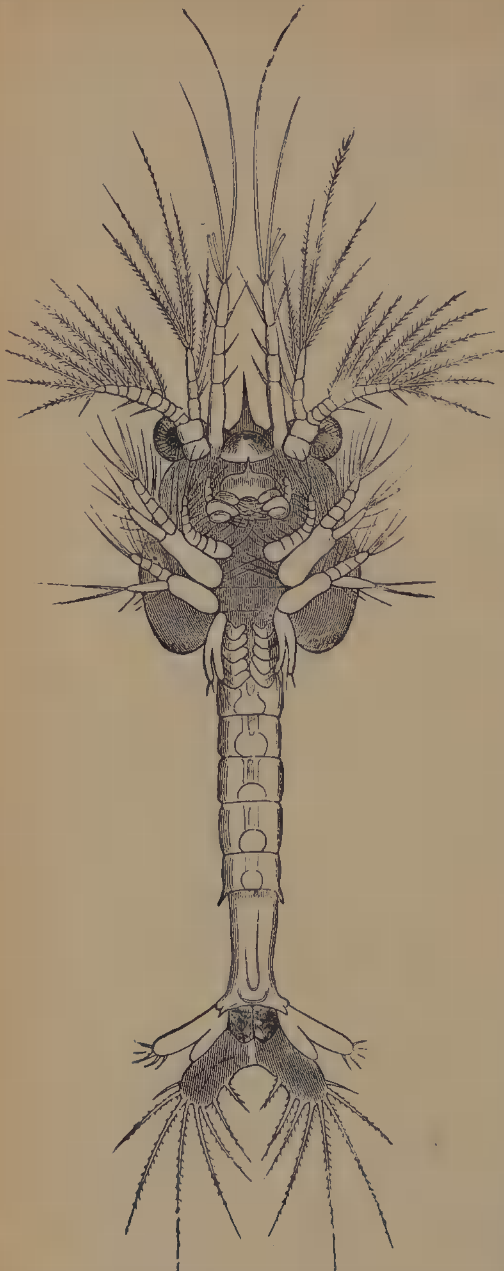


FIG. 107.—LIFE-HISTORY OF *Penæus*; A LATER STAGE.

forms than as representatives of ancestral crustaceans. Moreover, if one insists too much on the approximate parallelism between the life-history of the individual and the progress of the race, one is apt to overlook the deeper problem—how it is that the recapitulation occurs to the extent that it undoubtedly does. The organism has no feeling for history that it should tread a sometimes circuitous path, because its far-off ancestors did so. To some extent we may think of the inherited constitution as if it were the hand of the past upon the organism, compelling it to become thus or thus, but we must realise that this is a living not a dead hand; in other words, these metamorphoses have their efficient causes in the actual con-

ditions of growth and development. The suggestion of Kleinenberg referred to in a preceding chapter helps us, for if we ask why an animal develops a notochord only to have it rapidly replaced by a backbone, part of the answer surely is that the notochord which in the historical evolution supplied the foundation necessary for the evolution of a backbone, is still necessary in the individual history for its development.

Fig. 108.—Life-history of *Penæus*; Mysis Stage. (From Fritz Müller.)

It may be said that recapitulation is more clearly seen in the stages in the development of organs (organogenesis) than in the development of the organism as a whole. It must be remembered, moreover, that an organism is specific,—itself and no other from beginning to end. Thus although the frog illustrates recapitulation in its life-history, *e.g.* in the development of the heart and the circulation, and clearly reveals its piscine ancestry, it is specifically an Amphibian from first to last and through and through. The student should refer to Herbert Spencer's *Principles of Biology*, where the recapitulation idea is discussed in connection with the general idea of evolution as a progress from the homogeneous to the heterogeneous. About the same time (1866) Haeckel gave vivid illustrations of the recapitulation idea, stating it in his "fundamental biogenetic law": "Ontogeny, or the development of the individual, is a shortened

recapitulation of phylogeny, or the evolution of the race."

(*d*) *Organic Continuity*. In a subsequent chapter on heredity, which simply means the relation of organic continuity between successive generations, we shall explain the fundamental idea that the reproductive cells owe their power of developing, and of developing into organisms like the parents, to the fact that they are in a sense continuous with those which gave origin to the parents. A fertilised egg-cell with certain qualities divides and forms a "body" in which these qualities are expressed, distributed, and altered in many ways by division of labour. But it also forms reproductive cells, which do not share in the upbuilding of the body, which are reproductive cells in fact because they do not do so, because they retain the intrinsic qualities of the original fertilised ovum, because they preserve its protoplasmic tradition intact. This being so, it is natural and necessary that these cells, liberated in due time, should behave as those behaved whose qualities they retain. It is thus inevitable that like should beget like.

CHAPTER XVI

LIFE-HISTORIES

1. The curve of life—2. Larval periods—3. Prolonged embryonic life—4. Intricate life-histories—5. Prolonged youth—6. Adolescence—7. Senescence and rejuvenescence—8. Death—9. Retrospect.

1. **The Curve of Life.**—One of the most significant characteristics of living creatures is their "cyclical development." The life-span of one is counted in days and of another in months; we reckon our own in years and the Sequoia's in centuries, but there is for most an ascending curve from the vita minima of the egg-cell (which often dies in a few hours if it be not fertilised) to the vita maxima of full strength, and thence a descending curve to the vita minima of the outworn creature if the conditions of life admit of senescence. The animal ovum divides and redivides, and there is built up an embryo. This may develop steadily and directly into the likeness of its kind, as in the case of reptile, bird, and mammal; or it may give rise to a quite divergent phase—a larva of some sort—such as caterpillar or tadpole, which by and by undergoes metamorphosis and gets shunted on to the direct line of development. Through more or less critical phases of adolescence it becomes adult. It is a not infrequent achievement to lengthen out the period of mature strength, but sooner or later the edifice begins to crumble. "And so, from hour to hour, we ripe and ripe, and then, from hour to hour, we rot and rot, and thereby hangs a tale."

In life-histories in general we have before us the spectacle of a gradual movement towards a full epiphany, but the details are extraordinarily diverse. Life-histories

often differ from one another as different forms of a melody do when the "time" of the various parts is altered, and this change of rate is often finely adapted to particular conditions, that is to say, it furnishes a solution of special problems of life. The morphologists are beginning to discern that one type of skull, or one shape of fish, or one contour of leaf, may be derived from another by supposing a slight deformation—a tilting of axes, or an alteration of the angles at which the dominant lines meet—and an idea to be kept in mind in studying life-histories is that one creature's often differs from another's in a change of rate or rhythm, in an elongation of one part of the life-curve and a compression of another part.

2. **Larval Periods.**—The developing creature is called an embryo so long as it is within the egg-shell or egg-envelope. If what emerges from the egg is in the main a small edition of the parent, as in the case of a chick, we call it a young or juvenile creature; but if what emerges is built on different lines from the parent, we call it a larva, as in the case of a tadpole. The larva requires to undergo some degree of metamorphosis before it puts on the form of the adult; thus the life-history shows some circuitousness. This is very striking in cases where one larval form succeeds another, as in the Crustacean *Penæus* discussed in the last chapter.

A familiar kind of life-history is that into which a prolonged larval period has been interpolated. Out of the egg-shell of a cockroach or an earwig there comes a tiny creature which is in most respects a miniature of the adult, but out of a butterfly's egg there emerges a minute caterpillar which does not give much hint of its parentage. It feeds and grows and moults its cuticle, and this logical sequence is repeated over and over again. The caterpillar gains strength and stores up nutritive reserves—the so-called fatty body; it undergoes a remarkable metamorphosis, most of the larval body breaking down and a fresh start in development being made on a new architectural plan. After a period of quiescence (the pupa, or nymph, or chrysalis), which is often prolonged, the winged butterfly (the imago) emerges, as if by a

second birth, and enters upon a phase of life which is pre-occupied with reproduction and only secondarily (some-

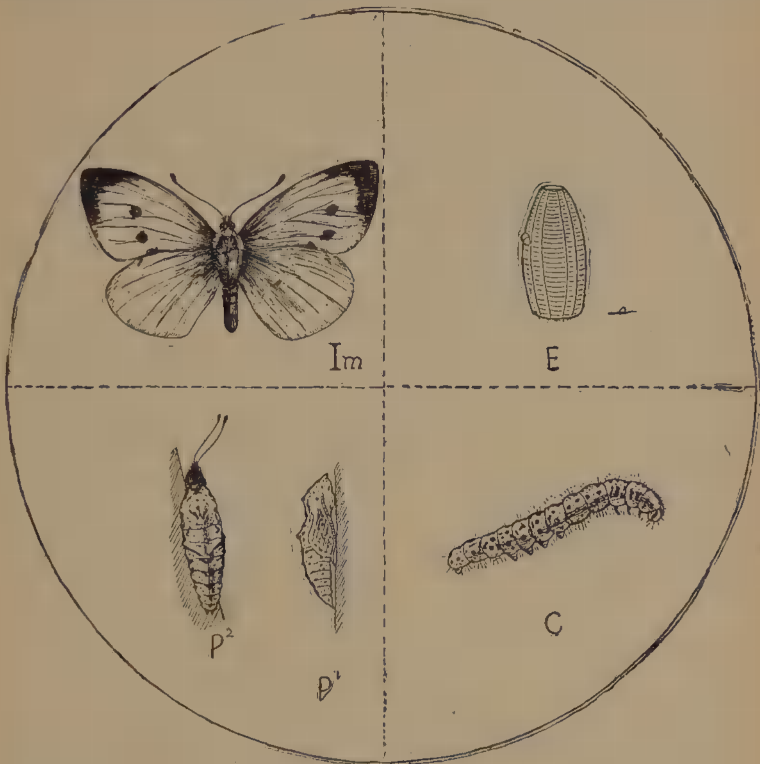


FIG. 109.—DIAGRAM OF THE LIFE-HISTORY OF A SMALL WHITE BUTTERFLY (*Pieris rapæ*).

Im, the imago, with knobbed antennæ and two pairs of scale-covered wings loosely linked together.

E, the egg very much enlarged. A small circle to the right is in proportion to the butterfly. The shell of the egg is made of chitin and beautifully sculptured. The head end of the unhatched caterpillar is protruding.

C, the caterpillar. It has a hard head and thirteen segments. The first three behind the head bear jointed clawed legs corresponding to the legs of the adult. Posteriorly there are five pairs of unjointed, unclawed pro-legs (see fig. 76).

*P*1, the early stage of the quiescent pupa. *P*2, a later stage from which the imago is beginning to emerge.

There are thus four chapters in the life-history: the egg and embryo; the larva; the pupa; and the imago.

times not at all) with nutrition. The active winged butterfly, to whom "love" means much and "hunger" little,

is undoubtedly a great achievement; the relatively long caterpillar period makes the ecstasy of the butterfly possible.

In many other life-histories we hear, so to speak, the same tune. There is a lengthening out of the larval period, a vantage-ground is slowly attained from which the adult form can begin afresh on different, usually more evolved, lines. The May-flies or Ephemerides previously referred to (p. 112) are often almost diagrammatic, for many of them have two or three years of sub-aquatic larval life and two or three days (or less) of aerial and reproductive activity.

In the sea-lamprey (*Petromyzon marinus*) there is a somewhat similar punctuation of life, but with a notable improvement, that the adult life is longer. The eggs are laid in a cleared space in the bed of a river and adhere to the sand and small pebbles; in about a fortnight ciliated larvæ emerge which burrow in the sand or mud and feed on small aquatic animals; they differ from the parents in the horseshoe shape of the mouth, in being blind, in the details of their respiratory system, and in some other ways. They remain larvæ for three or four years, after which they undergo a metamorphosis, losing their larval features and putting on those of the adult. They leave the fresh water and spend two or three years of vigorous life and rapid growth in the sea, feeding exclusively on fishes. Eventually they return to the rivers to spawn—the male shedding the seminal fluid or milt upon the eggs just as they are laid by the female. It is noteworthy that the setting in of reproduction is associated with a stoppage of nutrition, and the life-story, differing from that of the May-flies in the duration of the adult stage, ends in the same way, for death rapidly follows the spawning. The curve ends in the same way—an almost vertical drop after reproduction.

In the case of the common eel there is also a greatly elongated larval period, lasting it may be for a couple of years. Near the surface of the open sea where the European continental mass slopes down to the great abysses, and also in the mid-Atlantic, transparent, knife-

one that is very perfect at birth. It may be objected that most marine fishes are hatched as far from perfect larvæ, yet have to develop for a long time exposed to risks much greater than those that beset the young Cetacean. The answer is that this is only possible for fishes because they are so prolific. Their race can stand a prodigious juvenile mortality, unthinkable in the case of the slowly reproducing uniparous whale.

4. **Intricate Life-histories.**—In many cases the life-histories of animals are perplexing in their complications.[1] There is, for instance, the strangely circuitous development of most Echinoderms. The newly hatched diffusely ciliated larvæ of sea-urchins, sea-cucumbers, starfishes, and brittle-stars turn into extraordinarily shaped forms adapted to free-swimming in the open sea. After a time there begins within the larva a new formation, on a fresh architectural plan, utilising some of the previously established parts and rejecting others, and a miniature of the adult is formed. The wandering amœboid cells which play so diverse and so important a rôle in the animal kingdom are very active, at once as sappers and miners in breaking down the old, and as builders in constructing the new.

In the familiar case of gnats or mosquitoes, the eggs, which are moored in little rafts to water-weed, hatch into quaint dark-coloured larvæ, with slender bristly bodies, mouth-parts that waft in food-particles, and a valved breathing tube at the end of the tail with which they perforate the surface-film of the pool. They feed and grow and moult, and at the fourth moult a pupa emerges, light-brown in colour, with a large head and a small body, with two anterior breathing tubes and no open mouth. After a few days the pupa husk splits and the winged insect escapes into the air. There could hardly be a more zig-zag life-history.

Prolonged Youth.—In higher animals, but most notably among mammals, there is an interesting tendency

[1] A large number of life-histories have been described in the chapter on "The Cycle of Life" in the author's *Wonder of Life*. (Melrose, London, 1914.)

to prolong the juvenile period, when the young animals are well cared for and given freedom to experiment without too serious responsibilities. Groos in his *Play of Animals* has worked out the idea that this play-period is eminently educative of powers which are essential in after-life. It also affords opportunity for the emergence of variations before too stern and rigorous selection begins. Animals, Groos says, do not simply play because they are young; they continue young that they may play. "For play is the young form of work, and the animals who played best when young, worked best, lived best, perhaps loved best, when they grew up." [1] In his *Childhood of Animals* Dr. Chalmers Mitchell has expounded the important thesis that the purpose of youth is to give time for the breaking down of rigid instincts, and their replacement by action controlled by experience and memory, by remembered results of experiment. To put it in another way, youth is the time when co-ordinations are established between the instinctive processes of the lower brain-centres and the intelligent processes of the cerebral cortex. Thus has youth—especially prolonged youth—been justified in the past; so is it justified every day.

Adolescence.—In the higher reaches of life it is possible to distinguish between youth and mature strength a period of adolescence. "This is an arc on the up-grade, when juvenile characters are shed and adult characters put on. There is a final acceleration of growth (which suggests the value of a correlated abundance of rest and play and food); there are internal rearrangements and readjustments; there is a sifting of idiosyncrasies, to wit variations; there is a selective criticism of that veneer which we call modifications or individually acquired characters; and there is more than a beginning of sex-impulses." [2]

Senescence and Rejuvenescence.—Many reasons have been given to account for an organism growing old.

[1] The author's *Biology of the Seasons*, p. 227. (Melrose, London, 1911.)
[2] The author's *Wonder of Life*, p. 410. (Melrose, London, 1914.)

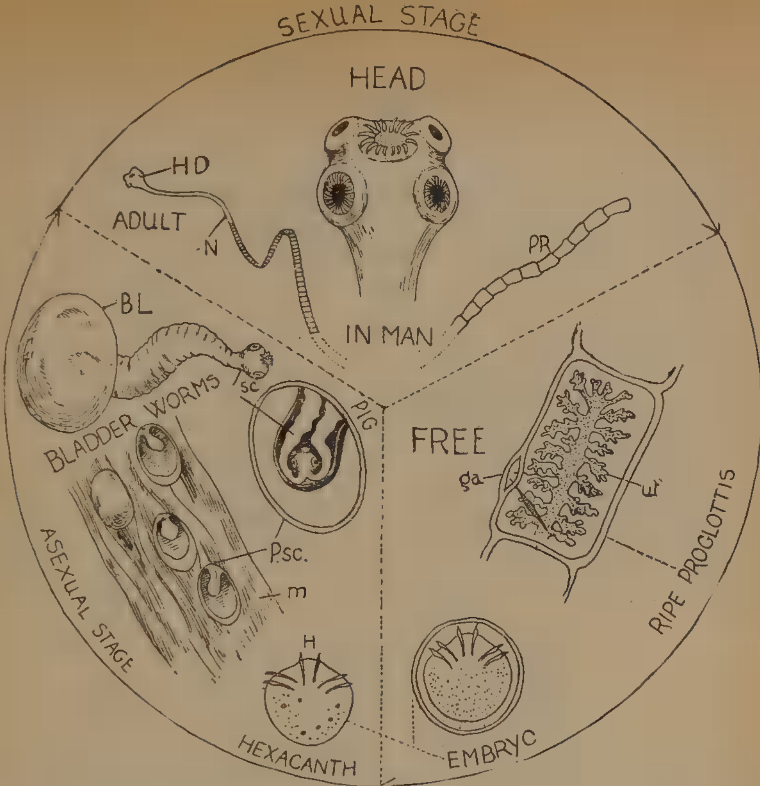


FIG. 110.—DIAGRAMMATIC REPRESENTATION OF THE LIFE-HISTORY OF *Tænia solium*, A COMMON TAPEWORM IN MAN, WITH ITS BLADDER-WORM STAGE IN THE PIG.

The sexual tapeworm lives in man's intestine, unaffected by the digestive juice, absorbing by its whole surface the digested food of its host. It is attached to the wall of the intestine by a head (*HD*), about the size of a pin's head; on this head there are four suckers which have to do with adhesion only (there is no mouth nor food-canal), and there is also a circle of minute gripping hooks. Behind the head there is a growing area or neck (*N*) where joints or proglottids (*PR*) are always being formed. The chain of joints, which change in shape as they grow older and are pushed further from the head, may be several yards long and is like a piece of white tape. Each joint has a complete set of hermaphrodite reproductive organs, and self-fertilisation (autogamy) occurs.

The ripe joints at the end of the tape-like chain (often called a strobila) contain only a branched uterus (*ut*) full of enshelled developing eggs. The genital aperture (*ga*) is seen at the side, but the eggs are eventually liberated by the bursting of the proglottis and uterus. This happens when the last proglottis is separated off and passes out with the fæcal matter. The microscopic egg-shells may be carried by runlets of water or by wind; they are very resistant. The life-history is not continued unless a pig swallow the microscopic enshelled embryo.

In the pig's stomach the shell is dissolved and a six-hooked (hexacanth) embryo is liberated. It bores its way to the muscles (*m*) and there settles down. It loses its hooks, increases in size, and becomes a passive, vegetative, asexual bladderworm or proscolex (*Psc*). An ingrowing bud from the wall of the bladder forms the future "head," or scolex (*Sc*). This is afterwards everted, and then the bladderworm consists of a small head attached by a short neck to a bladder (*BL*) about the size of a small pea. If man unwittingly eats the imperfectly cooked "measly" pork, the head fixes itself to the wall of his intestine and buds off a chain of joints. The chances are happily several millions to one against an enshelled embryo becoming a tapeworm.

It has been regarded as due to the slow accumulation of poisons, which may be waste-products of metabolism or the results of bacterial activity in the intestine, and so on. It has been regarded as due to the wearing-out of parts, especially of elements like nerve-cells, which do not multiply after an early stage in development. It has been referred to a cumulative disproportion between cell-substance (cytoplasm) and nuclear-substance (nucleoplasm); to a smothering with the results of incomplete combustion; to the diminishing activity of the glands of internal secretion; and so forth.

It may be, however, that all these are symptoms or results of something more fundamental, and we find some satisfaction in the general theory developed by Prof. C. M. Child in his interesting treatise, *Senescence and Rejuvenescence* (1915). On his view, which has a broad experimental basis, "the process of progressive development and differentiation in the individual is accompanied by a decrease in the metabolic rate determined by the accumulation of relatively inactive constituents in the protoplasm." The process of differentiation implies a formation of stable frameworks which it is difficult to keep young. Rejuvenescence is continually going on, the removal of the accumulated relatively inactive material, and this makes possible a reacceleration in metabolic rate. As Child says, the metabolic stream erodes its bed instead of depositing more materials. This rejuvenescence is so successfully achieved in Protozoa and simple animals like Hydra, that they do not grow old at all; in higher forms, however, rejuvenescence lags and senescence wins.

Child finds that when a fragment of Planarian worm regrows a whole there is a marked rejuvenescence during the period of reconstitution, the rate of metabolism is high and the resistance power (to cyanide poisons and the like) is great. Measured by these tests, the regenerating piece is younger than it was when it formed part of the parent. It renews its youth.

Similarly, when a Planarian or a Hydroid multiplies asexually, the separated piece shows marked reju-

venescence, as is shown by its rate of metabolism, that being measured, as before, by the degree of susceptibility and resistance to cyanides and the like, or by Tashiro's "biometer," an extraordinarily delicate register of the CO_2 output. The new individuals which arise by division or budding are to some extent physiologically younger than the parent.

In the higher animals the task of rejuvenescence is hopeless as far as the individual is concerned. The evil day may be staved off, but arrears accumulate, and processes of senescence gain on processes of rejuvenescence. It is interesting to notice, however, that Child finds some evidence that the early development stages of a number of animal types, before bodily specialisation sets in, are conspicuously young in the physiological sense. There may be a rejuvenescence at the beginning of the individual life which keeps the race young while the individuals pass away.

Death.—There are three chief kinds of death—(*a*) violent or extrinsic, (*b*) parasitic or microbic, and (*c*) natural. (*a*) A very large number of animals seem in the ordinary course of nature to die a violent or extrinsic death. They are devoured by their enemies or killed by vicissitudes in their environment, often while still in their prime.

(*b*) When an animal enters a new habitat, or when it comes into association with a novel source of infection, it is often fatally attacked by some microbe or by some larger parasite,—to which it is unaccustomed, and to which it can offer no internal resistance in the way of counteractive chemical substances (antibodies) or otherwise. Thus we know how man and his stock are often fatally attacked by new parasites in tropical countries. This is well illustrated in the case of the trypanosomes transferred by tse-tse flies from wild animals, which have become accustomed to them, to man and cattle where successful resistance can only be attained artificially.

(*c*) Natural death is more or less successfully evaded by the Protozoa, which have no "body" to keep up, and can continually recuperate their wear and tear, which

furthermore have very inexpensive modes of multiplication. The same may be more or less true of simple animals like Hydra and Planarian worms. "Natural death is incident (1) on the complexity of the bodily machinery, which makes complete recuperation well-nigh impossible, and almost forces the organism to accumulate arrears, to go into debt to itself; (2) on the limits that are set to the multiplication and renewal of cells within the body, thus the number of nerve-cells in higher animals cannot be added to after an early stage in development; and (3) on the occurrence of organically expensive modes of reproduction, for reproduction is often the beginning of death. At the same time, it seems difficult to rest satisfied with these and other physiological reasons, and we fall back on the selectionist view that the duration of life has been, in part at least, punctuated from without and in reference to large issues; it has been gradually regulated in adaptation to the welfare of the species.[1]

Retrospect.—Just as there are many novels but only a few plots, so amid an apparent multiplicity of life-histories we discern but a few main types. The details may seem very different, but they are often interpretable as due to a lengthening out here and a condensation there, to a changing of the time of the tune. This seems to be a guiding idea in the study of life-histories.

Just as there are in organisms architectural variations which find expression in spatial rearrangement of materials (comparable to those we see a schoolboy effecting with his "meccano," out of which he constructs now a crane and again a bridge, to-day a railway truck and to-morrow an aeroplane), so there are temporal variations which find expression in changes in the rate of growth and development, or in alterations in the rhythm or punctuation of life. In this connection it is interesting to remember that in the internal secretions (of backboned animals at least) there is a means by which the rate of growth and development can be automatically regulated. How suggestive, too, is the result of Gudernatsch's experiments

[1] The author's *Wonder of Life*, p. 442. (Melrose, London, 1914.)

on tadpoles, that a thyroid diet stimulates differentiation and hinders growth, while a thymus diet inhibits differentiation and lets growth go on.

The general idea is that the span of life is like a dis-

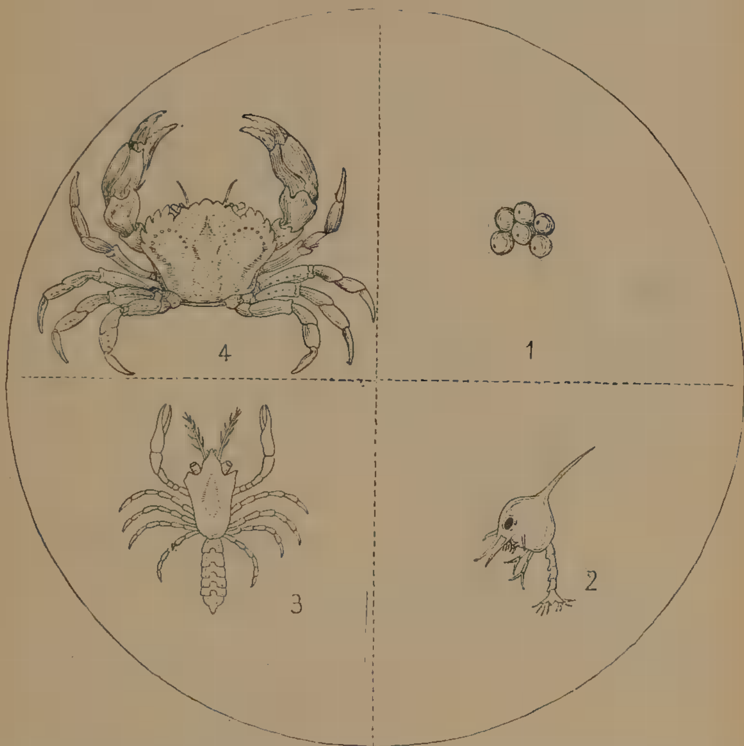


FIG. 111.—DIAGRAMMATIC REPRESENTATION OF THE LIFE-HISTORY OF THE COMMON SHORE-CRAB (*Carcinus mænas*).

1. The spherical eggs with chitinous envelopes. They show partial peripheral segmentation around a central core of yolk. They develop attached to the swimmerets of the mother.
2. The Zoæa larva, which is hatched from the egg and lives a free-swimming life in open water. It is to begin with about the size of a pin's head. It has paired compound eyes, a spine on the dorsal surface of its cephalothoracic shield (see the figure of the crayfish, p. 250). It has eight pairs of appendages—from the antennules to the third maxillipedes. The segmented abdomen sticks out behind. It feeds and grows and moults and eventually becomes a Megalopa (3).
3. The Megalopa is more like a lobster than a crab, for the abdomen is still in a line with the cephalothorax. The forceps and walking-legs are developed.
4. The abdomen is subsequently tucked upwards and forwards under the cephalothorax; the adult form has been assumed; the young crab has ceased to be much of a swimmer and has become a shore-animal.

continuously elastic thread, with non-extensible intervals here and there, and that the tension of the several parts can be altered in adaption to particular conditions. This is part of the tactics of evolution, and it is interesting to observe the diversity of the problems that alterations in the tempo of life are made to solve. The open-sea larval period in crabs and rock-lobster, in sea-urchins and star-fishes, secures diffusion and saves the delicate young life from the intolerable rough-and-tumble conditions of the shore. The medusoid, or swimming-bell period (sexed) in the life-history of many a zoophyte or hydroid colony (see "alternation of generations," p. **305**) probably secures the advantage of cross-fertilisation.

The very general suppression of the free-swimming larval stages in river animals (excepting cases such as insect larvæ, where gripping organs are well developed) is evidently an adaption against the risks of being washed down to the sea or being borne into an equally fatal stagnant backwater. In birds nesting in safe places there is often a long fledgling period, which corresponds to prolonged infancy; in ground birds, where the risks are greater, the young are usually precocious and able to run about soon after hatching. The relatively large eggs of mound-birds are produced at intervals, and incubation is impossible; the young, hatched in a heap of fermenting vegetation, are able to fly right away. In young as in adult there is a suppression of a chapter.

A telescoping of not only larval periods, but of youth itself into a prolonged embryonic development in sheltered conditions may mean that circumstances are too tyrannous for delicate young lives. In many mammals, as we have already hinted, the prolongation of the antenatal period may have something to do with the perfecting of a fine organisation, able from birth, in many cases, to cope with the exigencies of life. Robert Chambers, the author of the once-famous *Vestiges of Creation*, was surely right in insisting that the embryo's biding its time within the womb was as precious to it as it was costly to the mother. It meant bigger and finer brains.

Just as there are plants which remain for life like half-

opened buds, and others which flower before they leaf, so there are animals which have a long youth and others a long maturity, some that are born old and others that die young; some which break down suddenly in their prime, and others that seem to have no limit (save violent death) to their persistent growth. It is a question of vital punctuation, and the question rises whether some of the contrasts between different types may not have arisen in the course of evolution by not very startling alterations in the timing of life, in the rate and rhythm of metabolism.

Finally we would note that while man is a slowly varying creature, changing but little from age to age in the *organic* punctuation of his life, he is eminently plastic or modifiable, and therefore able, probably to an extent unsuspected, to lengthen out his youth, to prolong his period of cerebral variability, and to shorten the days of undesirable senescence. In all of which there is a great hope.

PART IV

THE EVOLUTION OF ANIMAL LIFE

CHAPTER XVII

THE EVIDENCES OF EVOLUTION

1. The idea of evolution—2. Arguments for evolution: Physiological, Morphological, Historical.

We observe animals in their native haunts, and study their growth, their maturity, their loves, their struggles, and their death; we collect, name, preserve, and classify them; we analyse them with various instruments and get to know their organs, tissues, and cells; we go back upon their life and inquire into the secret working of their innermost parts; we ransack the rocks for the remains of those animals which lived ages ago upon the earth; we watch how the chick is formed within the egg, and yet we are not satisfied. We seem to hear snatches of music which we cannot combine. We seek some unifying idea, some conception of the manner in which the world of life has become what it is.

1. **The Idea of Evolution.**—We do not dream now, as men dreamed once, that all has been as it is since all emerged from the mist of an unthinkable beginning; nor can we believe now, as men believed once, that all came into its present state of being by a flash of Almighty volition. Thus Erasmus Darwin (1794), speaking of Hume, says "he concluded that the world itself might have been generated rather than created; that it might have been gradually produced from very small beginnings, increasing

by the activity of its inherent principles, rather than by a sudden evolution of the whole by the Almighty fiat." In short, we have extended to the world around us man's characteristic conception of human history. The evolution idea means that the present is the child of the past and the parent of the future. "As in the development of a fugue," Samuel Butler says, "where, when the subject and counter-subject have been announced, there must thenceforth be nothing new, and yet all must be new, so throughout organic nature—which is a fugue developed to great length from a very simple subject—everything is linked on to and grows out of that which comes next to it in order—errors and omissions excepted."

When an egg by a series of changes becomes a chick, we speak of *development*. It is one organism throughout, though no one unaware of the facts could have predicted the end from the beginning. An implicit organisation becomes explicit in a very wonderful way. Somewhat in the same way we should speak of the development of the solar system, and the development of our earth. For if we call this evolution we are apt to forget that in organic evolution there is the continual elimination of the unsuccessful. The result at any given time represents only a very small fraction of the antecedents that led up to it. In fact, the term evolution is best kept for the realm of organisms.

2. Arguments for Evolution.—What then are the facts which have convinced naturalists that the plants and the animals of to-day are descended from others of a simpler sort, and the latter from yet simpler ancestors, and so on, back and back to those first forms in which all that succeeded were implied? The best answer is in Darwin's *Origin of Species*, where the arguments were marshalled in such a masterly fashion that they won the conviction of the world. Darwin's arguments were derived (*a*) from the distribution of animals in space; (*b*) from their successive appearance in time; (*c*) from actual variations observed in domestication, cultivation, and in nature; (*d*) from facts of structure, *e.g.* homologous and rudimentary organs; (*e*) from embryology. We shall simply

illustrate the different kinds of evidence, and that under three heads—physiological, structural, and historical.

Physiological. — Living creatures are variable from generation to generation. Even in the short span of a human life transformations may be observed to be in process. The "mutations" thrown off by some of the evening primroses, and especially by *Œnothera lamarckiana*, are both numerous and striking, and give us a vivid impression of the copiousness of the fountain of change that sometimes wells up in living creatures. One of the most striking cases in the Natural History Collection of the British Museum is that near the entrance, where on a tree are perched domesticated pigeons of many sorts—fantail, pouter, tumbler, and the like—while in the centre is the ancestral rock-dove, *Columba livia*, from which we know that all the rest have been derived. In other domesticated animals, and in cultivated plants, like the many different forms of cabbage, we may find similar direct evidence of evolution. But what occurs under man's supervision in the domestication of animals and in the cultivation of plants has its analogue at least in the state of nature. The offspring of a brood differ from one another and from their parents. How many strange sports there are and how unceasing the crop of minor fluctuations. Those who say they see no variation now going on in nature should try a month's work at identifying species.

Morphological.—There are said to be over half a million species of living animals, about half of them insects. The fact that we can make at least a plausible genealogical tree of animals, arranging them in series along the lines of hypothetical pedigree, is suggestive.

Throughout long series, structures fundamentally the same appear with varied form and function; the same bones and muscles are twisted into a variety of shapes. What differences in detail there are between the anterior limb of a frog, the paddle of a turtle, the wing of a bird, the flipper of a whale, the fore-leg of a horse, and the arm of man—and yet in all there are the same fundamental bones and muscles. Why this adherence to type if animals

FIG. 112.—VARIETIES OF DOMESTIC PIGEONS ARRANGED AROUND THE ANCESTRAL ROCK-DOVE (*Columba livia*).
(Based on Darwin's figures.)

are independent of one another? How necessary it is if all are branches of one tree.

By rudimentary organs also the same conclusion is suggested. What mean the unused gill-clefts of reptiles, birds, and mammals, unless the ancestors of these classes were fish-like; what mean the two sets of functionless teeth in unborn whale-bone whales, unless they are vestiges of useful teeth which their ancestors possessed? Similar vestiges are common among the higher animals. In man alone there are about seventy little things which might be termed rudimentary; our body is a museum of relics.

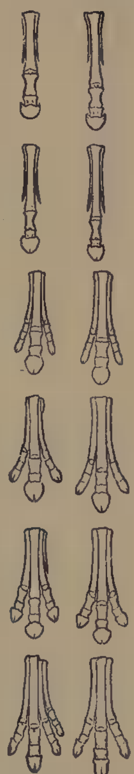


FIG. 113.—FORE AND HIND FEET OF THE HORSE AND SOME OF ITS ANCESTORS, SHOWING GRADUAL REDUCTION OF DIGITS.
(From Chambers's *Encyclop.*; after Marsh.)

Historical.—Every one recognises that animals have not always been as they now are; we have only to dig to be convinced that the fauna of the earth has had a history. But it does not follow that the succession of fauna after fauna, age after age, has been a progressive evolution. What evidence is there of this?

In the first place, there is the general fact that fishes appear before amphibians, and these before reptiles, and these before birds, and that the same correspondence between order of appearance and structural rank is often true in detail within the separate classes of animals. There are some marvellously complete series of fossils, especially, perhaps, that of the extinct cuttlefishes, in which the steps of progressive evolution are still traceable. Moreover, the long pedigree of some animals, such as the elephant or the horse, has been worked out so perfectly that more convincing

demonstration is hardly possible. The story has been often told, how in early Eocene times there lived small quadrupeds, about the size of sheep, that walked securely upon five toes, how these animals lost, first the inner toe, while the third grew larger, and then the fifth; how the third continued to grow larger and the second and fourth to become smaller until they disappeared almost entirely, remaining only as small splint bones; and how thus the light-footed runners on tiptoe of the dry plains were evolved from the short-legged, splay-footed plodders of the Eocene marshes (fig. 113). There are many extinct types which link order to order and even class to class, such as *Phenacodus* (fig. 97), which seems to occupy a central position in the mammalian series, so numerous are its affinities, or such as *Archæopteryx*, which links crawling reptile to soaring bird.

Another historical argument of great importance is that derived from the study of the geographical distribution of animals, but this cannot be appreciated without studying the detailed facts. These suggest that the various types of animals have spread from definite centres, along convenient paths of diffusion, varying into species after species as their range extended.

But the history of the individual is even more instructive. In a general way, especially as regards the development of particular organs, the individual proceeds step by step along a path approximately parallel to the presumed progress of the race, so far as that is traceable from the successive grades of structure and from the records of the rocks. Even in details such as the development of antlers on stags the parallelism of racial and individual history is hinted at (fig. 114). Of this correspondence it is difficult to see any elucidation except that the individual in its life-history in great part retreads the path of ancestral evolution.

We have illustrated these evidences of evolution very briefly, for they have been stated many times. The gist of the matter is that the evolution idea is a modal interpretation of the way in which the present state of things has come to be; it is the only scientific interpretation in

the field; and the evidences of it are all the facts which it illumines. The idea of evolution has also justified itself by the light which it has cast not only on biological, but on physical, psychological, and sociological facts. There has never been a more germinal idea; it has become organic in all our thinking.

To those who feel a repugnance to the doctrine of descent, we suggest two considerations:—

Just as we do not think a tree less stately because we know the tiny seed from which it grew, nor any man less noble because he was once a little child, so we ought

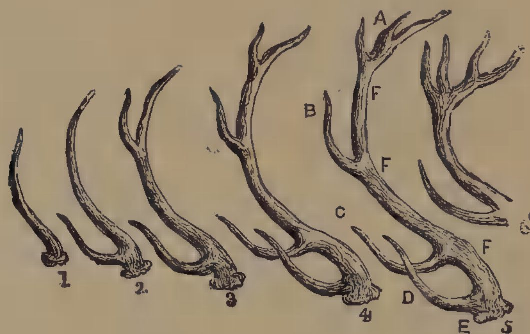


FIG. 114.—ANTLERS OF DEER (1–5) IN SUCCESSIVE YEARS; BUT THE FIGURE MIGHT ALMOST REPRESENT AT THE SAME TIME THE DEGREE OF EVOLUTION EXHIBITED BY THE ANTLERS OF DEER IN SUCCESSIVE AGES.

(From Chambers's *Encyclop.*)

not to look on the world of life with eyes less full of wonder or reverence, even if we feel that we know something of its humble origins.

Moreover, we should be careful to distinguish between the doctrine of natural descent, which, to most naturalists, seems a fact, and the theories of evolution which explain how the progressive descent was brought about. For in regard to the causal, as distinguished from the modal explanation of the world, we are still very uncertain.

As to the beginning of the whole process—the origin of organisms upon the earth, we know nothing, but hold various opinions. It is no dogma, nor yet a "law of Biogenesis," but a fact of experience, to which no excep-

tion has been demonstrated, that living organisms arise from pre-existent organisms—*Omne vivum e vivo*. But it may not always have been so.

It is believed by some that life began independently of those natural conditions which come within the ken of scientific inquirers; in other words, it is believed that the first living things were created. But this is foreclosing scientific inquiry in unjustifiable haste.

It has been suggested that germs of life reached this earth in the bosom of meteorites or otherwise from somewhere else. But this merely shifts the responsibility of the problem off the shoulders of this planet.

It is also suggested that organisms may have arisen from not-living matter on the earth's surface. But it is very difficult to think out concretely how such a marvellous step might be taken. If we accept the suggestion, we must suppose that in not-living matter the qualities characteristic of living organisms are somehow implicit. The evolutionist's common denominator is then as inexpressibly marvellous as the philosopher's greatest common measure. For there is nothing in the end which was not in kind in the beginning also.

CHAPTER XVIII

PAST HISTORY

1. The two records—2. Imperfection of the geological record—3. Palæontological series—4. Extinction of types—5. Relative antiquity of animals—6. Great steps in evolution—7. The ascent of man.

1. The Two Records.—Reviewing the development of the chick, W. K. Parker said, " Whilst at work I seemed to myself to have been endeavouring to decipher a palimpsest, and that not erased and written upon just once, but five or six times over. Having erased, as it were, the characters of the culminating type—those of the gaudy Indian bird—I seemed to be amongst the sombre grouse, and then, towards incubation, the characters of the Sand-Grouse and Hemipod stood out before me. Rubbing these away, in my downward walk, the form of the Tinamou looked me in the face; then the aberrant Ostrich seemed to be described in large archaic characters; a little while and these faded into what could just be read off as pertaining to the Sea Turtle; whilst, underlying the whole, the Fish in its simplest Myxinoid form could be traced in morphological hieroglyphics."

There is another palimpsest—the geological record written in the rocks. For beneath the forms which disappeared, as it were, yesterday—the Dodo and the Solitaire, the Moa and the Mammoth, the Cave Lion and the Irish Elk—there are mammals and birds of old-fashioned type the like of which no longer live. Beneath these lie the giant reptiles, beneath these great amphibians, preceded by hosts of armoured fishes, beyond the

first traces of which only backboneless animals are found. Yet throughout the chapters of this record, written during different æons on the earth's surface, persistent forms recur from age to age, a few of them, such as some of the lamp-shells or Brachiopods, living on from near the apparent beginning even until now. But other races, like the Trilobites, have died out, leaving none which we can regard as in any sense their direct descendants. Other sets of animals, like the Ganoid fishes, grow in strength, attain a golden age of prosperous success, and wane away. As the earth grew older, nobler forms appeared, and this history from the tombs, like that from the cradles of animals, shows throughout a gradual increase of differentiation and integration. It must always be borne in mind, however, that a type which is on the whole of low degree may show extraordinary complexity and harmony in detail.

2. Imperfection of the Geological Record.—If complete records of past ages were safely buried in treasure-houses such as some historians have proposed to make for the enlightenment of posterity, then palæontology would be easy. Then a genealogical tree connecting the Protist and Man would be possible, for we should have under our eyes what is now but a dream—a complete record of the past.

The record of the rocks is often compared to a library in which shelves have been destroyed and confused, in which most of the sets of volumes are incomplete, and most of the individual books much damaged. When we consider the softness of many animals, the chances against their being entombed, and the history of the earth's crust, our wonder is that the record is so complete as it is, that from "the strange graveyards of the buried past" we can learn so much about the life that once was.

We must not suppose the record to be as imperfect as our knowledge of it. Thus many regions of the earth's surface have been very partially studied, many have not been explored at all, many are inaccessible beneath the sea.

As to the record, the rocks in which fossils are found

are sedimentary rocks formed under water, often they have been unmade and remade, burnt and denuded. The chances against preservation are many.

Soft animals rarely admit of preservation, those living on land and in the air are much less likely to be preserved than those living in water, the corpses of animals are often devoured or dissolved. Again the chances against preservation are many.

3. **Palæontological Series.**—Imperfect as the geological record is, several marvellously complete series of related animals have been disentombed. Thus, a series of fossilised freshwater snails (*Planorbis*) has been carefully worked out; its extremes are very different, but the distinctions between any two of the intermediate forms are hardly perceptible. The same is true in regard to another set of freshwater snails (*Paludina*), and on a much larger scale among the extinct cuttlefishes (Ammonites, etc.) whose shells have been thoroughly preserved. The modern crocodiles are linked by many intermediate forms to their extinct ancestors, and the modern horse to its pigmy progenitors. In cases like these, the evidences of continuously progressive evolution are conclusive.

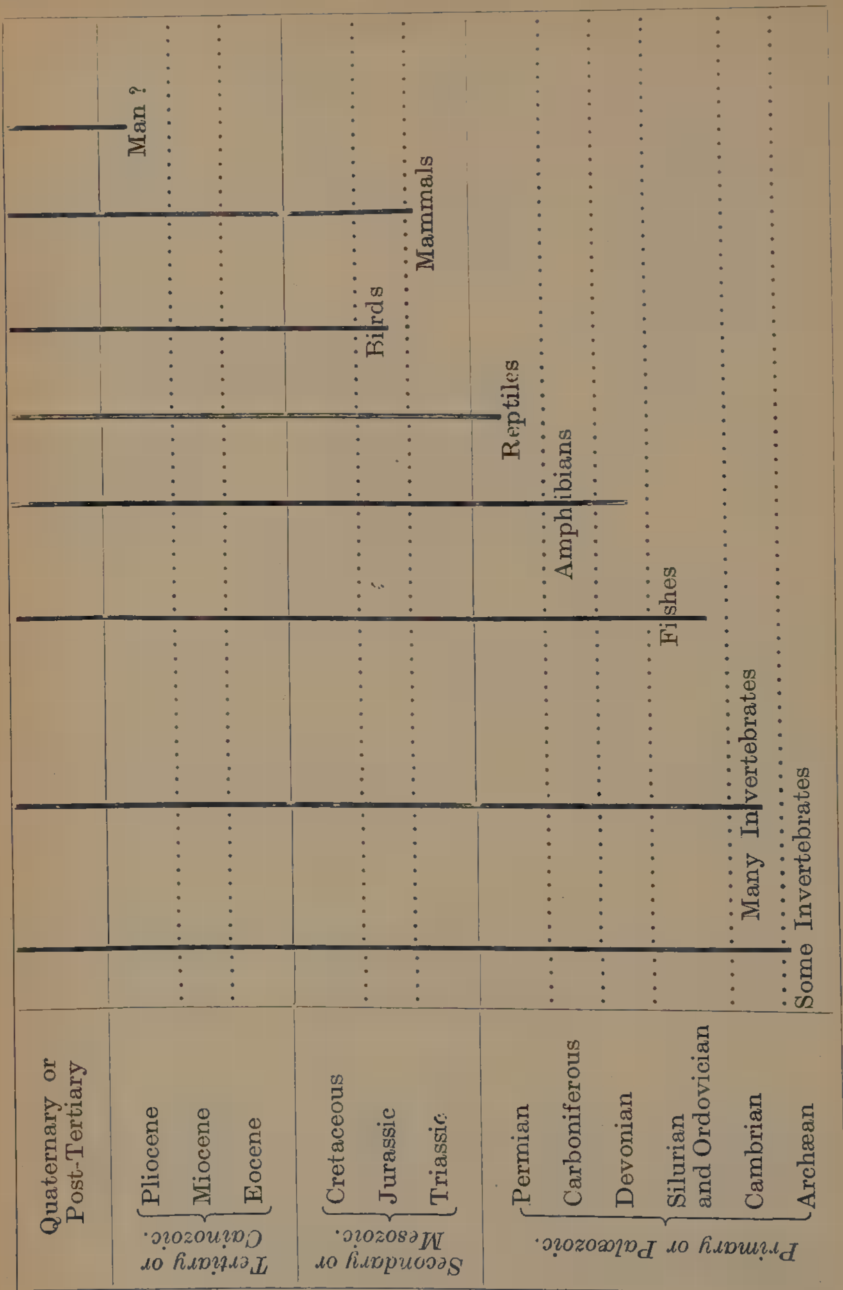
4. **Extinction of Types.** A few animals, such as some of the lamp-shells or Brachiopods, have persisted from almost the oldest rock-recorded ages till now. In most cases, however, the character of the family or order or class has gradually changed, and though the ancient forms are no longer represented, their descendants are with us. There is a disappearance of individuals and a slow change of species.

On the other hand there are not a few fossil animals which have become wholly extinct, whose type is not represented in the modern fauna. Thus there are no animals alive that can be regarded as the lineal descendants of Trilobites and Eurypterids, of relatively simple forms, such as Graptolites, which may have been Zoophytes, or of highly specialised types like the Flying Dragons or Pterodactyls. There is no doubt that a race may die out. Of the many different kinds of heavily armoured Ganoid fishes which abounded in the ages when

the Old Red Sandstone was formed, there are few survivors to-day. The New Zealand lizard, Sphenodon or Hatteria, is the sole survivor of an ancient race, and the same may be said of the king-crab (*Limulus*), another "living fossil."

It is difficult to explain why some of the old types disappeared. The extinction was never sudden. Formidable competitors may have helped to weed out some; for cuttlefish would tend to exterminate trilobites, and voracious fishes would decimate cuttlefish, just as man himself is rapidly and inexcusably annihilating many kinds of beasts and birds. But, apart from the struggle with competitors, it is likely that some types were insufficiently plastic to save themselves from changes of environment, and it seems likely that others were victims to their own constitutions, becoming too large, or too sluggish, or too calcareous; or, on the other hand, too feverishly active. The "scouts" of evolution would be apt to become martyrs to progress; the "laggards" in the race would tend to become pillars of salt; the path of success was oftenest a *via media* of compromise. Samuel Butler has some evidence for saying that "the race is not in the long run to the phenomenally swift, nor the battle to the phenomenally strong; but to the good average all-round organism that is alike shy of radical crotchets and old-world obstructiveness."

5. Relative Antiquity of Animals.—We have not much satisfaction in submitting the following table showing the relative antiquity of the higher animals. Such a table is only an approximation; it does not suggest the great differences in the duration of the various periods, nor how the classes of animals waxed and waned, nor how some types in these classes dropped off while others persisted. But the general fact which the table shows is true,—in the course of time higher and higher forms of life have come into being. It is possible to offer explanations of some apparent difficulties, *e.g.* that the earliest known mammalian fossils precede those of the earliest known bird fossils, for the two classes are on quite different lines of evolution; the big fact is certain that throughout the ages life has been slowly creeping upwards.


Quaternary or Post-Tertiary
Tertiary or Cainozoic.
Pliocene
Miocene
Eocene
Secondary or Mesozoic.
Cretaceous
Jurassic
Triassic
Primary or Palæozoic.
Permian
Carboniferous
Devonian
Silurian and Ordovician
Cambrian
Archæan
Man ?
Mammals
Birds
Reptiles
Amphibians
Fishes
Many Invertebrates
Some Invertebrates

6. **Great Steps in Evolution.**—It was only after many millions of years had passed that the earth became cool enough to be a home of life, and the origin of living organisms upon it remains shrouded in mystery. It may be that germs came from elsewhere, as Richter, Helmholtz, and Lord Kelvin suggested, but it is difficult to think of protoplasm surviving transport through space even in the heart of a meteorite. In any case, if the suggestion be true, the problem of origin is simply shifted, not solved. The probabilities are stronger in favour of the suggestion that living organisms of a simple sort evolved somewhere on earth from not-living matter; in other words, that spontaneous generation occurred. Pflüger and Verworn have upheld the view that the cyanogen radical (CN) may have been the starting-point of the proteid molecule which is an essential constituent of all living matter. The idea that the living may have evolved from the not-living is in harmony with evolutionist thinking, but it is a very difficult hypothesis. The synthetic chemist is able to build up artificially a large number of complex substances, such as sugar, indigo, and salicylic acid, but he has not yet (1916) made proteids; we cannot suggest with much concreteness how there could be effected in nature's laboratory syntheses like those which man's directive reason achieves; and even the simplest organisms have qualities which we cannot explain in terms of any known properties of inorganic substance. On the other hand, unless organisms arose from the inorganic, their origin remains quite mysterious. But "if the dust of the earth did naturally give rise to living creatures, if they are in a real sense born of her and the sunshine, then the whole world becomes more continuous and vital, and all the inorganic groaning and travailing becomes more intelligible.[1]

First Organisms.—We have no means of knowing what the first organisms were like, but it is probable that they were extremely minute—like the nuclei of some of the Protists. The late Professor Minchin was strongly of opinion that the earliest living beings were minute, possibly

[1] *Evolution*, Geddes and Thomson, p. 72.

ultra-microscopic particles which were of the nature of the chromatin which forms a great part of the nucleus in all cells. He pictured them as specks of a substance like chromatin, yet with definite specific individuality, multiplying by binary fission, producing ferments, and building up protein molecules. A later step was the formation of an enveloping matrix of protoplasm and the differentiation of a nucleus. The question of these beginnings is wholly speculative, but the student should recognise that there may have been many stages before what we call a cell was evolved.

Plants and Animals.—One of the early steps must have been the differentiation of two great lines of evolution—the plant-line and the animal-line, whose resemblances and differences have been already considered (chapter XI). The cleavage depended on the production of the green pigment chlorophyll, for it plays an indispensable part in the "photosynthesis" which is the most fundamental process in animate nature. On the green plant's power of utilising the energy of the sunlight in the upbuilding of complex carbon-compounds from the raw materials of water, earth, and air, the whole life of plants, and therefore of animals, depends. The bifurcation between plants and animals may be regarded as expressing an alternative of two possible regimes, between a life with a relatively great preponderance of constructive, upbuilding, synthetic processes (anabolism) and a life in which there is a relatively large proportion of disruptive, down-breaking processes (katabolism)—an alternative which seems to have recurred frequently, in less pronounced antithesis, in the history of organisms. If $\frac{A}{K}$ expressed the average vital ratio of anabolism to katabolism in a plant and $\frac{a}{k}$ the same for an animal with the same weight of living matter (if that could be estimated), $\frac{A}{K}$ is much greater than $\frac{a}{k}$; in other words, the animal lives much more nearly up to its income than the plant does.

The Differentiation of Unicellular Animals.—When we take a survey of the kingdom of the unicellular or non-cellular animals, and try to avoid losing sight of the wood in our study of the trees, we recognise what Geddes has expounded in his conception of the cell-cycle, that there are three great pathways. On the one side, there are the highly active Infusorians, most of which move quickly by means of cilia or flagella; on the other side, there are sluggish and parasitic Sporozoa, which tend to sink into a passive encysted stage; and between the two are the amœboid Rhizopods, neither very active nor very passive, but representing a median compromise. These three lines correspond to three physiological regimes—of lavish expenditure and "living dangerously," of preponderant saving and a life of ease, and of balance between these extremes, which are obviously extremes of relatively high katabolism and relatively preponderant anabolism. The most primitive organisms, like some of the Proteomyxa and Myxomycetes, pass through a cycle of phases—from flagellate to amœboid, from amœboid to encysted, often with the interpolation of another—plasmodial—chapter, in which a number of minute amœboid units coalesce into one composite mass. The Infusorians, Sporozoa, and Rhizopods are, as it were, accentuations of the phases that occur in the life-history of the simplest, and often show traces of other phases besides the one that they mainly represent. The idea of the cell-cycle is corroborated by reference to multicellular animals, where we find illustrations of (1) very active cells, as in ciliated epithelium, (2) very passive cells, as in fatty tissue or in cartilage, and (3) amœboid cells like the white blood-corpuscles. Moreover, a spermatozoon is usually very active, like a flagellate Infusorian; a mature ovum is often encysted and quiescent, like a Sporozoon; while an immature ovum is often amœboid, as is well seen in the freshwater Hydra. When a young ovum accumulates reserves and becomes passive, or when ciliated or flagellate cells lapse into amœboid phase, we hear as it were echoes of the primitive cell-cycle.

Other Great Steps.—In the course of time there must

have arisen the first creatures with a "body"—the multicellular organisms. This was certainly one of the greatest steps in organic evolution. It was not till later that organs began to be differentiated, but tissues had their beginning in forms like Sponges. The first organs are seen in Cœlentera, and there also we can study the complication of individuality which arises by colony-making. Another great step was the differentiation of male and female multicellular organisms, on which, as we have already noticed, the multicellular Protozoon called Volvox sheds a vivid light.

In most Sponges and Cœlentera the symmetry of the body is radial and that is well suited for sedentary life and random drifting, but it was an eventful step when some worm-types first acquired definite bilateral symmetry, a right side and a left, a head end and a tail, and above all head-brains. The establishment of a chief motor, sensory, and co-ordinating centre in the anterior end must have had momentous consequences, and animal behaviour must have risen to a new plane.

The acquisition of a segmented body, paired appendages, and a body-cavity by Annelids marked another epoch, and we must not forget the differentiation of sense-organs and cross-striped, quickly contracting muscle, and such an important discovery on the organism's part as hæmoglobin—the oxygen-capturing pigment of the blood which first appears in Nemertean worms. Remarkable external armature and jointed appendages were among the gains of the Arthropods.

One of the epoch-making events was the origin of Vertebrate animals, and then followed the gaining of skulls, jaws, paired fins, and bone itself. Amphibians were the first to have fingers and toes, true lungs, a voice, and a mobile tongue. Among Reptiles we first find the important ante-natal robes (or fœtal membranes), and the crocodile gained a four-chambered heart. Birds and mammals are the only warm-blooded animals, and show a great heightening of brain-development. In all mammals except a few primitive types there is a placenta binding the unborn young to its mother in intimate symbiosis.

These are but a few of the great events of animal evolution, but enough perhaps to prompt the student to develop further an interesting line of inquiry.

One of the most general results of evolution is complexifying. Things become more intricate. This is true of the inter-relationships that become established in the web of life; the threads make more intricate knots in the economy of birds than in that of sponges. It is true also of behaviour; the big-brained mammal symbolised in Brer Rabbit is a subtle creature, and even the low type of brain-development represented by bony fishes belongs to a different epoch from the medusæ under whose umbrella they shelter. It is true also of the internal economy of the body, which is more intricate in an insect than in a polyp, in a bird than in fish. As we ascend the series, the variety of internal activities increases—there are more different kinds of metabolism—and the subtlety of correlation increases. The different processes work more perfectly into one another's hands. Finally, the tendency to complexify is seen in structure, where we have to do with the other side of the complexifying of function to which we have just alluded. It is important to realise, however, that the structural complexifying which counts in evolution is in the direction of increased organisation. The architecture of the flinty skeleton of Venus's Flower Basket (Euplectella) is intricate, yet it does not amount to much more than the endless repetition of a certain kind of scaffolding. Its intricacy is quite different from that of the cortex of a dog's cerebral hemispheres, in which innumerable nerve-cells, with complex interrelations, are organised into a unity. In the quaint masticatory, respiratory, and locomotor apparatus known as Aristotle's Lantern in sea-urchins, there are twenty-five or more calcareous pieces, but this sort of complexity, finely as it works, is on a relatively low plane compared with that of, let us say, a dog's head. We would advise the student to give reality to his impressions by securing practical familiarity with some representative specimens of complexity of structural organisation (see fig. 115).

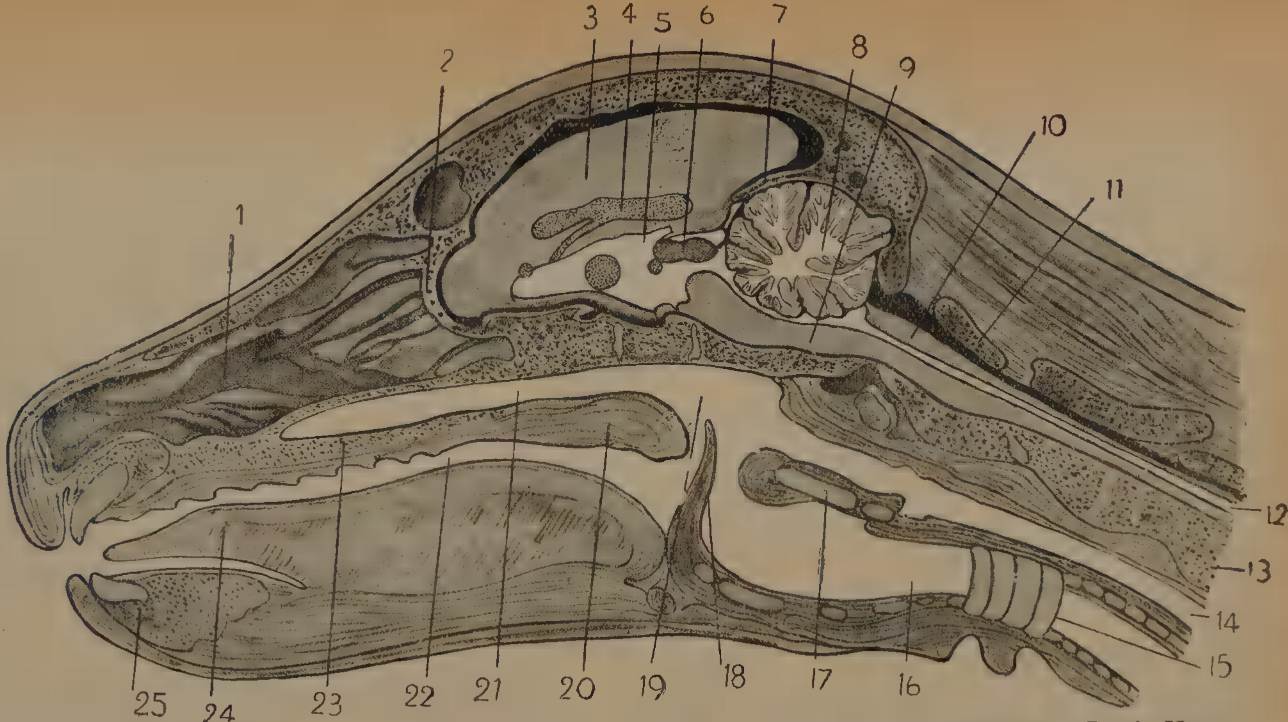


Fig. 115.—Diagrammatic Representation of a Median Vertical Section through a Dog's Head.

(From a specimen. It is introduced in this book simply as a slight indication of structural complexity.)

1. Nasal chamber, in which the olfactory membrane is spread on turbinal bones twisted like scrolls. 2. Cribriform plate, **the bone** (mesethmoid) in front of the cranial cavity perforated by holes through which branches of the olfactory nerve pass to the **nasal** chamber. 3. Cerebral hemisphere. 4. Corpus callosum, a bridge of nerve fibres binding the two hemispheres into **functional unity.** 5. The third ventricle or cavity of the optic thalami, from which the pineal body ascends and the pituitary body descends. Three commissures are shown cut across. 6. The optic lobes or corpora quadrigemina—the third part of the brain. 7. The tentorium cerebelli, a bony partition which comes down for some distance between the cerebrum (3) and the cerebellum (8). The bones of the skull are dotted. 9. The floor of the medulla oblongata, the fifth part of the brain. 10. The roof of the spinal cord. 11. Base of the neural arch of a vertebra. 12. The cerebro-spinal canal, a ciliated canal passing down the middle of the spinal cord. 13. The centrum of a vertebra. 14. The gullet or œsophagus. 15. One of the gristly rings of the trachea or windpipe. 16. The trachea just behind the larynx. 17. One of the cartilages of the larynx. 18. The epiglottis, the movable lid which protects the glottis or opening of the windpipe. 19. The posterior end of the nasal passage. 20. The soft palate. 21. The nasal passage.

7. **The Ascent of Man.**—In one of the works of Broca, a pioneer anthropologist of renown, there is an eloquent apology for those who find it useful to consider man's zoological relations.

"Pride," he says, "which is one of the most characteristic traits of our nature, has prevailed with many minds over the calm testimony of reason. Like the Roman emperors who, enervated by all their power, ended by denying their character as men—in fact, by believing themselves demigods—so the king of our planet pleases himself by imagining that the vile animal, subject to his caprices, cannot have anything in common with *his* peculiar nature. The proximity of the monkey vexes him; it is not enough to be king of animals, he wishes to separate himself from his subjects by a deep unfathomable abyss; and, turning his back upon the earth, he takes refuge with his menaced majesty in a nebulous sphere, 'the human kingdom.' But anatomy, like that slave who followed the conqueror's chariot crying, *Memento te hominem esse*, anatomy comes to trouble man in his naïve self-admiration, reminding him of the visible tangible facts which bind him to the animals."

Let us hearken to this slave a little, remembering Pascal's maxims: "It is dangerous to show man too plainly how like he is to the animals, without, at the same time, reminding him of his greatness. It is equally unwise to impress him with his greatness, and not with his lowliness. It is worse to leave him in ignorance of both. But it is very profitable to recognise the two facts."

It is many years since Sir Richard Owen described the "all-pervading similitude of structure" between man and the highest monkeys. Subsequent research has continued to add corroborating details. As far as structure is concerned, there is much less difference between man and the gorilla than between the gorilla and a monkey like a marmoset. Yet differences between man and the anthropoid apes do exist. Thus man alone is thoroughly erect after his infancy is past, his head weighted with a heavy brain does not droop forward, and with his erect attitude his perfect development of vocal mechanism is

perhaps connected. We plant the soles of our feet flat on the ground, our great toes are usually in a line with the rest, and we have better heels than monkeys have, but no emphasis can be laid on the old distinction which separated two-handed men (Bimana) from the four-handed monkeys (Quadrumana), nor on the fact that man is peculiarly naked. We have a bigger forehead, a less protrusive face, smaller cheek-bones and eyebrow ridges, a true chin, and more uniform teeth than the anthropoid apes. More important, however, is the fact that the weight of the gorilla's brain bears to that of the smallest brain of an adult man the ratio of 2 : 3, and to the largest human brain the ratio of 1 : 3; in other words, a man may have a brain three times as heavy as that of a gorilla. The brain of a healthy human adult never weighs less than 31 or 32 ounces; the average human brain weighs 48 or 49 ounces; the heaviest gorilla brain does not exceed 20 ounces. "The cranial capacity is never less than 55 cubic inches in any normal human subject, while in the orang and the chimpanzee it is but 26 and 27½ cubic inches respectively." The cerebral cortex, the seat of intelligence, is said (by G. H. Parker) to include 9,200,000,000 nerve-cells, but these cells by themselves represent a little less than a cubic inch of material and weigh only 13 grammes!

But differences which can be measured and weighed give us little hint of the characteristically human powers of building up ideas and of cherishing ideals. It is not merely that man profits by his experience, as many animals do, but that he makes some kind of theory of it. It is not merely that he works for ends which are remote, as do birds and beavers, but that he controls his life according to conscious ideals of conduct. Man is solidary with the rest of creation, but he is also apart, as is plain when we think of his power of articulate speech, his realisation of his history, his inherent social sympathies, and his gentleness.

The arguments by which Darwin and others have sought to show that man arose from an ancestral type common to him and to the higher apes are the same as

those used to substantiate the general doctrine of descent. For the *Descent of Man* was but the expansion of a chapter in the *Origin of Species*; the arguments used to prove the origin of animal from animal were adapted to rationalise the ascent of man.

(1) *Physiological.*—The bodily life of man is like that of monkeys; both are subject to the same diseases; various human traits, such as gestures and expressions, are paralleled among the "brutes"; and children born during famine or in disease are often sadly ape-like. A remarkable physiological method of demonstrating blood-relationship by observing the reactions when two kinds of blood are mingled holds true in regard to man and the higher apes.

(2) *Morphological.*—The structure of man is like that of the anthropoid apes, none of his distinctive characters except that of a heavy brain being momentous, and there are about eighty vestigial structures in the muscular, skeletal, and other systems.

(3) *Historical.*—There is little certainty in regard to the fossil remains of prehistoric man, but some of these suggest more primitive types, while the facts known about ancient life show at least that there has been progress along certain lines. Moreover, there is the progress seen in each individual life, from the apparently simple egg-cell to the minute embryo, which is fashioned within the womb into the likeness of a child, and being born grows from stage to stage, all in a manner which it is hard to understand if man be not the outcome of a natural evolution.

As to the antiquity of the human race, big-brained men lived in Europe in the later stages of the Ice Age, and there are indications of human activity (implements) in Pliocene times. No fossils of the modern type of man have been found older than early Pleistocene. It is maintained by Prof. Arthur Keith[1] and others that the Neanderthal type (*Homo neanderthalensis*), co-existing with the modern type in mid-Pleistocene times, represented a distinct species, perhaps diverging from the main human stem in the early Pliocene, and not in the

[1] Keith, *The Antiquity of Man*, London, 1915.

direct line of our ancestry. To the Neanderthal line may be referred the Heidelberg man of the early Pleistocene. A second collateral line which has come to nothing is that represented by the Piltdown skull (*Eoanthropus dawsoni*) of the end of the Pliocene. A third collateral line, perhaps diverging in the Miocene, is represented by *Pithecanthropus erectus* at the end of the Pliocene. According to Keith, these three lines are separate offshoots—all eventually failures—diverging from the humanoid stem.

As it is certain that man could not have arisen from any of the known anthropoid apes, and as it is likely that he arose from a stock common to them and to him, it seems justifiable to date the antiquity of the human race not later than the time when the anthropoid apes are known to have been established as a distinct family. This takes us back to pre-Miocene ages. If we mean by the antiquity of man the period since the human stem differentiated from that which led on to the great anthropoid apes, it may be estimated (Keith and Sollas)[1] at about two million years. If we mean the period at which the brain of man reached a human level or standard, "we have," says Keith, "reasonable grounds for presuming that man had reached the human standard by the commencement of the Pliocene period,"—about a million years ago. Amid much uncertainty the general result of recent investigation is clear, that the modern type of man is vastly older than was supposed even in the days of Lyell's *Antiquity of Man* (1863).

Converging facts point to the conclusion that man arose as a mutation (a discontinuous variation of considerable magnitude) in a stock common to him and to the anthropoid apes. In regard to the factors which helped to secure man's ascent we can only speculate.[2]

(*a*) From what we know of men and monkeys, it seems likely that in the struggles of primitive man cunning was more important than strength, and if intelligence now became, more than ever before, the condition of life or death, wits would tend to develop rapidly.

[1] Sollas, *Ancient Hunters*, 1911.
[2] The author's *Outlines of Zoology*, 6th edition, 1914, p. 293.

(*b*) When habits of using sticks and stones, of building shelters, of living in families began—and some monkeys exhibit these—it is likely that wits would increase by leaps and bounds.

(*c*) Professor Fiske and others have emphasised the importance of prolonged infancy, and this must surely have helped to evolve the gentleness of mankind.

(*d*) Among many monkeys society has begun. Families combine for protection, and the combination favours the development both of emotional and intellectual strength. Surely "man did not make society, society made man."

CHAPTER XIX

HEREDITY

1. The facts of heredity—2. Theories of heredity—historical retrospect—3. The idea of the continuity of generations—4. Modes of inheritance—5. Social and ethical aspects.

In olden times men spoke of the three Fates which were believed to determine of what sort a life should be. With the decay of poetic feeling, and in the light of common science, the forms of the three sisters have faded. But they are realities still, for men are thinking more and more vividly about the factors of life. The biological factors are Heredity, Function, and Environment: the capital with which a life begins, the interest accruing from the investment of this in varied vital activities, and the force of circumstances. But while it is useful to think of Heredity, Function, and Environment as the three Fates, we must not mystify matters by talking as if these were entities acting upon the organism. They are simply aspects of the fact that the creature is born and lives. The inheritance includes all that the organism is or has to start with when it begins its life as a fertilised egg-cell, and heredity is only a name for the genetic relation between successive generations. Moreover, the functions of an organism depend upon the inherited *and* the acquired constitution, and so does its susceptibility to the influences of environment. Function includes all the actions and reactions between the living creature and its surroundings, and its influence may operate through disuse as well as through exercise.

We define heredity as *the relation of organic or genetic*

continuity between successive generations, choosing this definition because it is misleading to talk about "heredity" as a "basal principle in evolution," as a "great law," as a "power," or as a "cause." When we call heredity a "Fate," it is plain that we speak fancifully, but "principle" and "law" are dangerous words to play with. We cannot think of life without this organic relation between parents and offspring, and had species been created instead of having been evolved there would still be heredity.

1. **The Facts of Heredity.**—An animal sometimes arises as a bud from its parent, and in rare cases from an egg which requires no fertilisation, but apart from these exceptions every multicellular animal develops from an egg-cell with which a male-cell has united in an intimate way. The egg-cell supplies most of the initial living matter, but the nucleus of the fertilised egg-cell is formed in half from the nucleus of the immature ovum, in half from the nucleus of the spermatozoon. Each parent usually contributes the same amount of nuclear material —the same number of chromosomes—to the offspring, and this nuclear stuff is very essential.

In some cases (few as yet known) half of the spermatozoa have the same number of chromosomes as the ovum, while the others have one less. There is clear evidence in some of these cases that an egg fertilised by a spermatozoon with the same number of chromosomes develops into a female, while an egg fertilised by the other type of spermatozoon (with one chromosome less) develops into a male. The extra chromosome, which half of the spermatozoa have and half have not, is called the x-element or accessory chromosome, and it seems as if the presence of two x-elements in the fertilised ovum liberated the quality of femaleness, while in the presence of a single x-element maleness finds expression.

Another fact is more obvious, the offspring is very like its kind. One of the first things that people say about an infant is that it is like its father or its mother or some near relative, and the assertion does not arouse any surprise, although the statement, often more obviously true,

that the infant is like any other of the same race is received with contempt. But every one admits that "like begets like."

This likeness between offspring and parent is often far more than a general resemblance, for peculiar features and minute idiosyncrasies are frequently reproduced. Yet one must not assume that because a child twirls his thumbs in the same way as his father did, the habit has been inherited. For peculiar habits may readily reappear by imitation, and peculiarities of structure

FIG. 116.—DEVONSHIRE PONY, SHOWING THE OCCASIONAL OCCURRENCE OF ANCESTRAL STRIPES.

(From Darwin.)

because the offspring grow up in conditions similar to those in which the parents lived.

Abnormal as well as normal characters, innate in the parents, may reappear in their descendants, and the list of weaknesses and malformations which may be transmitted is long and grim. But care is required to distinguish between reappearance due to inheritance and reappearance due to similar conditions of life.

Then there is a strange series of facts showing that an organism may reproduce characteristics which the parents

did not exhibit, but which were possessed by a grandparent or remoter ancestor. Thus a lizard in growing a new tail to replace one that has been lost has been known to grow one with scales like those of an ancestral species. To find out a lizard's pedigree, a wit suggests that we need only pull off its tail. When such ancestral resemblance in ordinary generation is very marked, we call it "atavism" or "reversion," but of this there are many degrees. A boy "takes after his grandfather"; a horse occasionally exhibits stripes, perhaps harking back to those of a wild ancestor; a blue pigeon like the ancestral rock-dove sometimes results from crossing different races of pigeons; or a cultivated flower reverts to the simpler and more normal wild type. But many of the so-called "reversions" are due not to reawakenings of characters which have lain latent for ages, but to a coming-together-again of characters which have been analysed apart in previous generations. This is well illustrated among domesticated pigeons and rabbits, where it is not difficult to repack the box which has been unpacked in man's establishment of different races.

Every animal is usually a little different from its parents, and cannot be mistaken for one of its fellow-offspring, except in cases of "identical twins" which are believed to arise from one ovum divided into two separate halves. The proverbial "two peas" may be very unlike. Against the big fact of persistent hereditary resemblance is the fact of variability. The relation between successive generations is such that the offspring is on the whole like its parents, but various causes producing change diminish this likeness, so that we no longer say "like begets like," but "like *tends* to beget like."

2. Theories of Heredity—historical retrospect.—Theories of heredity, like those about many other facts, have been formulated at different times in different kinds of intellectual language—theological, metaphysical, and scientific—and the words are often more at variance than the ideas.

(*a*) *Theological Theories.*—It was an old idea that the germ of a new human life was possessed by a spirit, sometimes of second-hand origin, having previously belonged

to some ancestor or animal. So far as this idea persists in the minds of civilised men, it is much purified and sublimed. It raises the difficult question of the relation of mind and body.

(*b*) *Metaphysical Theories.*—For a time it was common to appeal to "*vires formativæ*," "hereditary tendencies," and "principles of heredity," by aid of which the germ grew into the likeness of the parent, and this tendency to resort to verbal explanations is hardly to be driven from the scientific mind except by intellectual asceticism.

(*c*) *Mystical Theories.*—During the eighteenth century and even within the limits of the enlightened nineteenth, a quaint idea of development prevailed, according to which the germ (either the ovum or the sperm) contained a miniature organism, preformed in all transparency, which only required to be unfolded (or "evolved," as they said), in order to become the future animal. Moreover, the egg of a fowl contained not only a micro-organism or miniature model of the chick, but likewise in increasing minuteness similar models of future generations. Micrcosm lay within microcosm, germ within germ, like the leaves within a bud awaiting successive unfolding, or like an infinite juggler's-box to the "evolution" of which there was no end. This "preformation theory" or "mystical hypothesis" was virtually but not actually shattered by Wolff's demonstration of "Epigenesis" or gradual development from an apparently simple rudiment. But the preformationists were right in insisting that the future organism lay (potentially) within the germ, and right also in supposing that the germ involved not only the organism into which it grew, but its descendants as well. The form of their theory, however, was crude and false.

(*d*) *Theories of Pangenesis.*—Scientific theories of heredity really begin with that of Herbert Spencer, who in 1864 suggested that "physiological units" derived from and capable of growth into cells were accumulated from the body into the reproductive elements, there to develop the characters of structures like those whence

they arose. At dates so widely separate as are suggested by the names of Democritus and Hippocrates, Paracelsus and Buffon, the same idea was expressed—that the germs consist of samples from the various parts of the body. But the theories of these authors were vague and in some respects entirely erroneous suggestions. The best-known form of this type of theory is Darwin's "provisional hypothesis of pangenesis" (1868), according to which (*a*) every cell of the body, not too highly differentiated, throws off characteristic gemmules, which (*b*) multiply by fission, retaining their peculiarities, and (*c*) become specially concentrated in the reproductive elements, where (*d*) in development they grow into cells like those from which they were originally given off. This theory was satisfactory in giving a reasonable explanation of many of the facts of heredity; it was unsatisfactory because it involved many unverified hypotheses.

3. **The Idea of the Continuity of Generations.**—In 1876 Jæger expressed his views explicitly as follows:

"Through a long series of generations the germinal protoplasm retains its specific properties, dividing in development into a portion which is reserved to form the reproductive material of the mature offspring."

This reservation, by which some of the germinal protoplasm is kept apart, during development and growth, from corporeal or external influences, and retains its specific or germinal characters intact and continuous with those of the parent ovum, Jæger regarded as the fundamental fact of heredity.

Brooks (1876, 1877, 1883) was not less clear:

"The ovum gives rise to the divergent cells of the organism, but also to cells like itself. The ovarian ova of the offspring are these latter cells or their direct unmodified descendants. The ovarian ova of the offspring thus share by direct inheritance all the properties of the fertilised ova."

But before and independently of either Jæger or Brooks, and yet more definitely, Galton had reached the same idea. From his experiments he was led in 1872 to the

conclusion that "the doctrine of pangenesis, pure and simple, is incorrect." His own view was that the fertilised ovum consisted of a sum of germs, gemmules, or organic units of some kind, to which in entirety he applied the term *stirp*. But he did not regard this nest of organic units as composed of contributions from all parts of the body. He regarded it as directly derived from a previous nest, namely, from the ovum which gave rise to the parent. He maintained that in development the bulk of the stirp grew into the body—as every one allows—but that a certain residue was kept apart from the development of the "body" to form the reproductive elements of the offspring. Thus, he said, in a sense the child is as old as the parent, for when the parent is developing from the ovum a residue of that ovum is kept apart to form the germ-cells, one of which may become a child. Besides Galton, Jæger, and Brooks, several other biologists suggested this fertile idea of the organic continuity of generations. It was recognised by Erasmus Darwin and by Owen, by Haeckel, Rauber, and Nussbaum. But it is to Weismann that the modern emphasis on the idea is chiefly due.

Let us try to realise this doctrine of organic continuity between generations. Let us begin with a fertilised egg-cell, and suppose it to have the potential qualities *abcxyz*. This endowed egg-cell divides and redivides, and for a short time each of the units in the ball of cells may be regarded as still possessing in equal measure the qualities *abcxyz*. But division of labour, and rearrangement, infolding and outfolding, soon begin, and most of the cells form the "body." They lose their primitive characters and uniformity, they become differentiated, the qualities *ab* find predominant expression in one set, *bc* in another, *xy* in another, and so on. It may be that all the qualities are possessed by all the cells, and that only two or three find expression while the others lie quite latent, like dormant seeds, unless some unusual stimulus calls them into expression. But while the body-making and the associated differentiation have been going on, certain cells have taken no share in it. They have remained

embryonic and undifferentiated, retaining the many-sidedness of the original egg-cell, preserving intact and uniformly the potential qualities *abcxyz*. They form the future reproductive cells—let us say the eggs.

Now when these eggs are liberated, with the original qualities *abcxyz* unchanged, having retained a continuous protoplasmic tradition with the parent ovum, they are evidently in almost the same position as that was. Therefore they develop into the same kind of organism. Given the same kinds of protoplasmic change or metabolism occurring in the same protoplasmic material, the same inherent qualities, the same conditions of birth and growth, the results *must* be the same. A single-celled animal with qualities *abcxyz* divides into two; each has presumably the qualities of the original unit; each grows rapidly into the form of the full-grown cell. We have no difficulty in understanding this. In the sexual reproduction of higher animals, the case is complicated by the formation of the "body," but logically the difficulty is not greater.

How far has this early separation of the future reproductive cells from the developing body been observed? It has been observed in several worm-types—leeches, *Sagitta*, thread-worms, Polyzoa,—in some Arthropods *e.g. Moina* and *Cyclops* among crustaceans, in *Chironomus* and some other Insects, Phalangidæ among spiders, and with less distinctness in a number of other organisms, both animal and vegetable. In many organisms, however, the future reproductive cells are not observable till development has proceeded for some time—it may be days or weeks longer. Thus we have to pass from cases of a demonstrable lineage of segregated germ-*cells* to Weismann's more general conception of "*the continuity of the germ-plasm*." "In each development," he said, "a portion of the specific germ-plasm contained in the parent egg-cell is not used up in the construction of the body of the offspring, but is reserved unchanged for the formation of the germ-cells of the following generation."

When we remember that a piece of a Begonia leaf, or

of a sponge, or of a polyp, or of a Planarian worm, and so on, will readily develop into an entire organism, we must recognise that in simple creatures at any rate the contrast between body-cells and germ-cells is not hard and fast. Experiments seem to show that these body-cells carry the entire inheritance, though only certain characters have found expression in them, the others lying latent. In higher animals, where differentiation has gone further, the regenerative capacity of a group of body-cells is much restricted. Yet the cases we have mentioned suggest that it is unwise to make too sharp a contrast between body-cells and germ-cells. The germ-cells are those cells which carry the whole inheritance without allowing any of it to find expression until appropriate conditions and stimuli are forthcoming. They carry it in a form little liable to extrinsic influence and yet readily admitting of development.

4. **Modes of Inheritance.**—Prediction of the result of pairing two organisms is apt to be falsified—for instance, because the expression of a particular character in development depends in part on other elements in the inheritance, and also in part on the available "nurture," such as the food, the temperature, the moisture, and so on. But there are some well-known alternatives of expectation, and in some cases the average result may be predicted with certainty. Let us consider the various modes of inheritance.

When similar forms are bred together for generations and those furthest from the mean persistently removed, a uniformity and constancy of character often results. Two parents produce offspring like themselves and like the rest of the herd. They are "pure-bred" and "breed true." It is believed that the hereditary items (or "determinants," or "factors," or "genes"—for they get many names) corresponding to a particular character are present uniformly in all the germ-cells of both the parents. Each has what all the rest have, none has what the others have not. To parents and offspring alike the technical term "homozygous" is applied. In such cases there will be a strong hereditary resemblance and to the

inexperienced eye all the individuals may seem alike. This is one extreme.

The other extreme is seen when an offspring is born that is in some feature or features very unlike its parents and kindred, exhibiting some novel pattern, some new position of organic equilibrium, in technical language a mutation or discontinuous variation. Such new departures have sometimes formed the beginning of a new domesticated breed or cultivated variety; and it is possible that new species in nature may sometimes have *begun* in this way. In mankind these mutations are illustrated by mathematical and musical geniuses, by children with marked originality, and by less desirable idiosyncrasies. The conditions of their appearance are not known.

Between the two extremes that we have mentioned there are two main modes of inheritance, which are contrasted as blended and alternative (or Mendelian), and there are many who think that what seem to be blends will eventually turn out to be complicated cases of Mendelian inheritance. Taking things as they are, however, there seem to be cases where the offspring as regards certain features exhibit what may be called an intimate blend of the paternal and maternal characteristics. Thus, though the case is not so easy as it seems, a mulatto is often regarded as illustrating in the colour of his skin a blending of paternal and maternal characters. Dr. E. Warren has described two hybrids between two kinds of cockatoos—*Cacatua galerita* (male) and *Licmetis nasica* (female), which appear to show a blending of the characters of the two parents. Out of ten characters the hybrids were nearer Cacatua in five, nearer Licmetis in one, and almost exactly intermediate in four. In every character examined, with the possible exception of the coloured and non-coloured lores (the space between the bill and the eye), there was a very obvious blending of the paternal and maternal characteristics. In a cross between a long-eared lop rabbit and a short-eared breed, Prof. Castle found that the offspring were intermediate in length of ears and in skeletal measurements, and that they bred true.

There are some curious cases, probably admitting of Mendelian explanation, where the offspring show what may be called a coarse-grained combination of the paternal and the maternal characteristics, the former appearing in one part of the body, the latter in another part, as when a light-coloured horse and a dark-coloured mare have a piebald foal, or when a sheep-dog has an eye like its father's on one side of the head, and an eye like its mother's on the other side. This is often described as *particulate* inheritance.

The mode of inheritance which is now called Mendelian was discovered in 1865 by Gregor Mendel (1822–1884), an Austro-Silesian abbot, who worked chiefly with the edible pea, *Pisum sativum*, which has many well-marked varieties, and is habitually self-fertilised. Mendel's work remained practically unknown till 1900, when De Vries, Correns, and Tschermak independently, and almost simultaneously, reached experimental results closely resembling Mendel's. The inquiry has been continued by many investigators, notably Bateson, Punnett, Castle, Cuénot, Morgan, and Davenport.

When Mendel crossed a pure-bred giant variety of pea with a pure-bred dwarf variety, the offspring were all tall. The character of tallness which appeared in the hybrid generation (F_1), to the exclusion of dwarfness, was called by Mendel the "dominant" character, the other being "recessive."

The tall cross-bred or hybrid peas were left to self-fertilise, which corresponds to close inbreeding or pairing of similars in animals, and in their progeny there were talls and dwarfs in the average proportions of 3 : 1; 75 per cent. talls and 25 per cent. dwarfs in the second filial or F_2 generation.

When the dwarfs of this F_2 generation were left to self-fertilise, their offspring in the F_3 generation were all dwarfs, and further generations bred from them also consisted exclusively of dwarfs. They may be called pure or extracted recessives, being "pure" as regards dwarfness.

But when the talls of the F_2 generation were left to

self-fertilise, their offspring in the F_3 generation were of two kinds. One-third of the F_2 talls (pure dominants) produced only talls; two-thirds of them (impure dominants) produced talls and dwarfs in the 3 : 1 proportion. Thus the F_2 generation, resulting from the self-fertilisation of the cross-bred forms or hybrids (F_1), consisted of 25 per cent. pure dominants, 50 per cent. externally similar impure dominants, and 25 per cent. pure recessives. This may be expressed in the accompanying scheme.

Parental Generation	Tall Variety		Dwarf variety . . .	P
First filial (hybrid) generation	all the offspring tall; self-fertilised they yielded		. . . . .	F_1
Second filial (inbred) generation . . .	25 p.c. Talls (pure dominants)	50 p.c. Talls (impure dominants)	25 p.c. Dwarfs (pure recessives) . .	F_2
	Talls	25 p.c. Talls (pure) 50 p.c. Talls (impure) 25 p.c. Dwarfs (pure)	Dwarfs . .	F_3

When the peculiar "waltzing mice" are crossed with normal mice, the offspring (F_1) are all normal. The waltzing habit is recessive. But when the offspring are inbred, their progeny (F_2) are normal mice and waltzers in the proportion of 3 : 1. The recessive waltzers of this generation might be sold as pure waltzers, for if paired with others like themselves they will yield only waltzers, and that in spite of the fact that their parents were normal, as also was one of their grandparents! But the normals of the F_2 generations, though

all alike in external appearance, turn out to be of two kinds when they are used in breeding; one-third of them (*pure dominants*) will yield only normal mice; the other two-thirds (*impure dominants*) will split up again, when inbred, into normal mice and waltzing mice in the old average proportions of 3 : 1.

Using D for organisms with the dominant character (or, what will come to the same thing, with a character which is absent in the organisms with which they are paired); R for organisms with the corresponding recessive character (or the absence of the character which the dominants have); and D(R) for forms with dominant character expressed and the recessive character latent (as subsequent breeding shows), the facts may be expressed, after Punnett, in the following scheme:—

Parents		D R	
First Filial Generation (F_1)		D(R)	
Second Filial Generation (F_2)	1D (pure dominants)	+ 2D(R) (impure dominants) +	1R (pure recessives)
Third Filial Generation (F_3)	D	1D + 2D(R) + 1R	R

Mendelian inheritance is exhibited when the parent forms have contrasted characters (allelomorphs) which do not blend, or when one has a particular well-defined character (say horns or a crest) which is absent in the other. As we shall afterwards see, the important point is not the difference in the expression of the character, but the condition of the germ-cells as regards the factor, determinant, or gene corresponding to the character. Since the beginning of the twentieth century Mendelian characters have been demonstrated in diverse types, of which some illustration may be given.

ANIMALS

Dominant Character	*Recessive Character*
Hornlessness in cattle.	Presence of horns.
Normal short hair in rabbits and guinea-pigs.	Long "Angora" hair.
Short tail in Manx cat (somewhat imperfectly dominant).	Normal length of tail.
Normal movements in mice.	Waltzing in mice.
Crest in poultry.	Absence of crest.
Rose comb and Pea comb.	Single comb.
Extra toes.	Normal four toes.
Broodiness.	Absence of this instinct.
Unbanded shell in wood-snail.	Banded shell.
Greyness in mouse.	Albinism in mouse.
Pink eye in fruit-fly.	White eye in fruit-fly.

PLANTS

Dominant Character	*Recessive Character*
Peas :—	
Tall stems.	Dwarf stems.
Yellow cotyledons.	Green cotyledons.
Brown-skinned seeds.	White seeds.
Round seeds.	Wrinkled seeds.
Wheat :—	
Absence of awn.	Presence of awn.
Rough and red chaff.	Smooth and white chaff.
Keeled glumes.	Rounded glumes.
Flinty endosperm.	Floury endosperm.
Susceptibility to rust.	Immunity to rust.
Barley :—Two-rowed ears.	Six-rowed ears.
Nettles :—Markedly dentate leaves.	Slightly dentate leaves.

Why one character is dominant and another recessive we cannot tell, nor do we know if there is a quality common to all dominant characters and a quality common to all recessive characters. A glance at the representative list will show that there is great variety in the characters which exhibit Mendelian inheritance. In mankind the best illustrations are furnished by brachydactylism (where the fingers are all thumbs, two joints instead of three), by night-blindness (a condition of the eye apparently due to the absence of the visual purple), and by the colour of the iris.

It may be of interest to refer to cases where the parents differ in *two* pairs of contrasted characters (or allelomorphs), *e.g.* when a tall yellow-seeded pea (both characters dominant) is crossed with a dwarf green-seeded pea (both characters recessive). The hybrid offspring (F_1) are all tall yellows, but what will their offspring be? If we suppose that there are 16 of them, three-fourths (12) will be tall and one-fourth (4) dwarf. But of the 12 talls, three-fourths (9) will be yellow-seeded and one-fourth (3) green-seeded. And of the 4 dwarfs likewise, three-fourths (3) will be yellow-seeded, and one-fourth (1) green-seeded. So the formula for "dihybridism" runs, in this case: 9 tall yellow + 3 tall green + 3 dwarf yellow + 1 dwarf green. This may be conveniently registered on a scheme:—

TY	TY	TY	TY
TY	TY	TY	TY
TY	Tg	Tg	Tg
dY	dY	dY	dg

A very instructive illustration of Mendelian inheritance is given by Professor Punnett,—that of the Blue Andalusian fowl (see fig. 118). The Blue Andalusians are known not to breed true; they yield, besides blues, two sorts of "wasters," namely blacks and whites marked with some black splashes. The blacks breed true, the whites breed true, but the blues will not. The reason is plainly that Blue Andalusians are impure dominants, D(R), the blacks and the white being the pure types. The student should linger over this case, for it illustrates what very frequently occurs, that the F_1 generation does not, as regards the character in question, resemble one parent exclusively, but is incomplete in its expression of dominance. It might be readily mistaken for a blend, but the subsequent history, as the diagram shows, corrects the misinterpretation.

Let us now in reference to the Andalusian fowl illus-

trate, following Prof. Punnett, what may be called Mendel's theory as distinguished from his rule. In the black fowls, every germ-cell, whether ovum or spermatozoon, is supposed to bear a representative factor for blackness. The black birds are "homozygous" as regards blackness. Similarly the germ-cells or gametes of the white fowls bear a representative factor for whiteness and none for blackness. When a "black" egg-cell is fertilised by a "black" spermatozoon, the result will be a black bird. But when a "black" egg-cell is fertilised by a "white" spermatozoon, or a "white" egg-cell by a "black" spermatozoon, the resulting zygote (the fertilised egg-cell) will contain the representatives or factors or genes for both blackness and whiteness, and will develop into a *blue* bird, which is technically "heterozygous" as regards blackness and whiteness.

Now what Mendel shrewdly suggested was that in the history of the germ-cells within the hybrid (F_1) form there is a segregation of the contrasted factors, so that half the germ-cells have the one and half have the other. Half of the ova have the dominant factor and half the recessive factor because of this segregation into two contingents. Half of the spermatozoa similarly carry the dominant factor and half the recessive factor. Then, if fertilisation

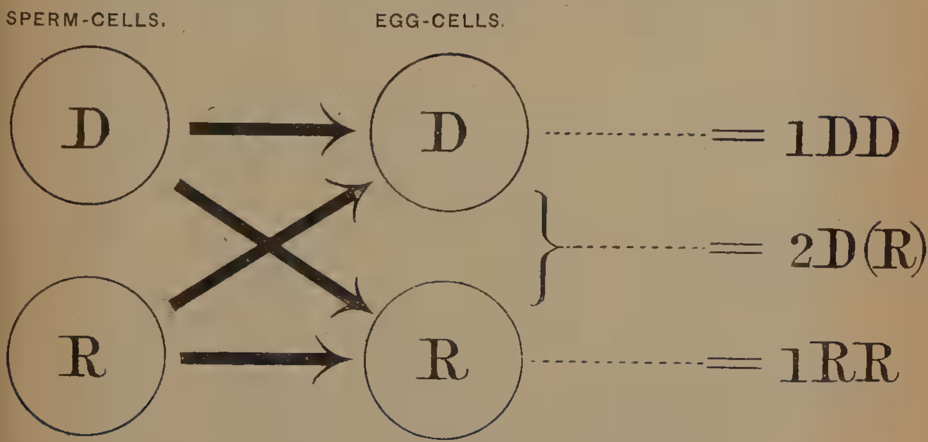


FIG. 117.—DIAGRAM ILLUSTRATING MENDELISM.

be fortuitous, the proportions 1DD + 2D(R) + 1RR must result.

As Professor Punnett puts it :

"A blue hen is producing equal numbers of 'black' and 'white' eggs—let us say $2n$ of each. To fertilise these eggs are brought large numbers of spermatozoa of the two sorts, black and white, in equal numbers. Every black egg, then, has an equal chance of being fertilised by a black or a white spermatozoon. In the former case it will form a black, and in the latter a blue, bird. From our $2n$ black eggs we shall obtain n black and n blue birds; that is to say, the mating of blue with blue must, on the assumption of the purity of the gametes, give black, blue, and white in the ratio 1 : 2 : 1."

The theory of gametic segregation is at the centre of Mendelian theory. As Professor Bateson says :—

"The essential part of the discovery is the evidence that the germ-cells or gametes produced by cross-bred organisms may in respect of given characters be of the pure parental types, and consequently incapable of transmitting the opposite character; that when such pure similar gametes are united in fertilisation, the individuals so formed and their posterity are free from all taint of the cross; that there may be, in short, perfect or almost perfect discontinuity between these germs in respect of one of each pair of opposite characters."

5. **Social and Ethical Aspects.**—All the important biological conclusions have a human interest.

The fact of organic continuity between germ and germ helps us to realise that the child is virtually as old as the parent, and that the main line of hereditary connection is not so much that between parent and child as "that between the sets of elements out of which the personal parents had been evolved, and the set out of which the personal child was evolved." "The main line," Galton says, "may be rudely likened to the chain of a necklace, and the personalities to pendants attached to the links." To this fact social inertia is largely due, for the organic stability secured by germinal continuity tends to hinder evolution by leaps and bounds either forwards or backwards. There is some resemblance between the formula of heredity and the first law of motion. The practical corollary is respect for a good stock.

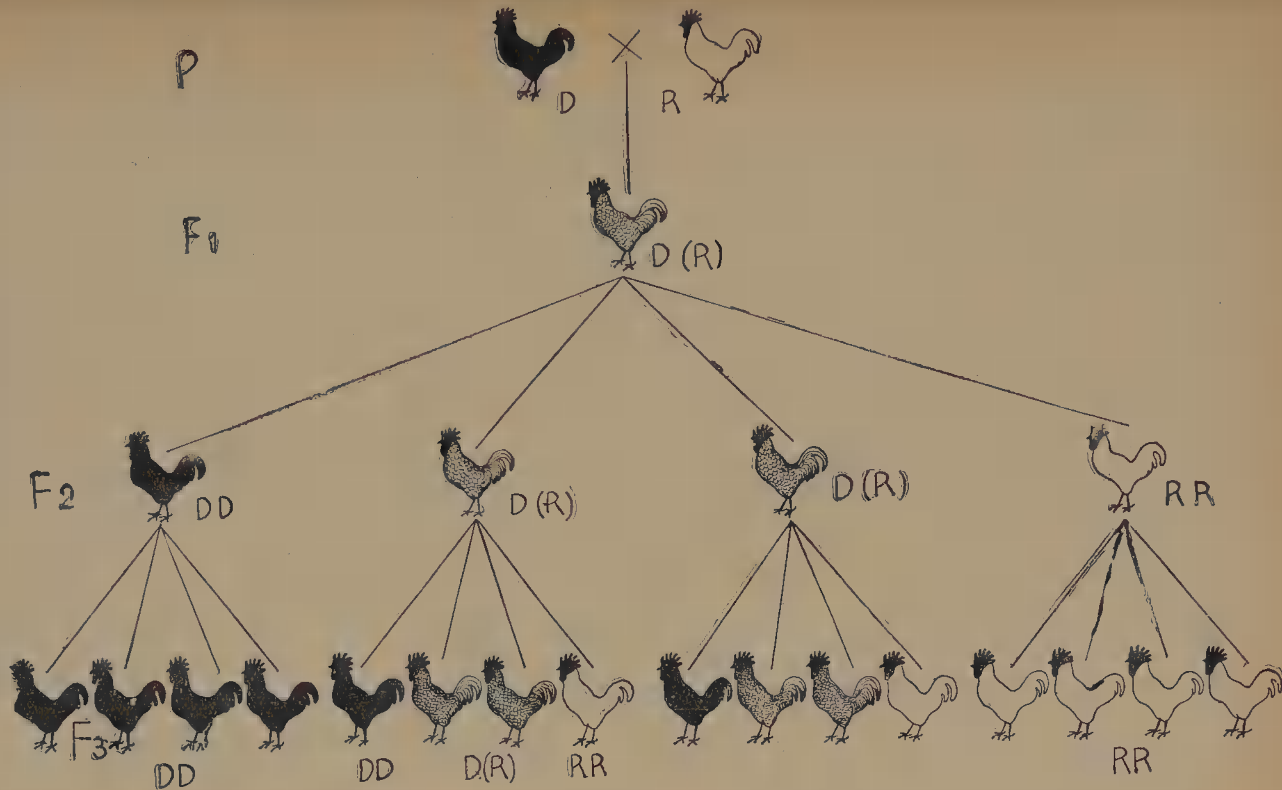


FIG. 118.—DIAGRAM ILLUSTRATING MENDELIAN INHERITANCE IN THE CASE OF THE ANDALUSIAN FOWL.
(Drawn by permission of the late Mr. A. D. Darbishire and Messrs. Cassell from a figure in *Breeding and the Mendelian Discovery* (1911)).

P, the parents, black (dominant) and white (recessive).
F_1, the hybrid generation, blue.
F_2, the second filial generation, blacks (DD), whites (RR) (with occasional black points), and blues, $D(R)$.
F_3, the third filial generation.

That each parent contributes almost equally to the offspring suggests the two-sided responsibility of parentage. As regards Mendelian characters the offspring will show with more or less completeness the dominant characters of its parents; as regards blending characters the inheritance is probably in the first instance dual, but beyond that multiple, for ancestral contributions may go to build up the final mosaic result.

If we adopt Weismann's conclusion that individually acquired modifications are not transmitted, we are saved from the pessimism suggested by the abnormal functions and environments of our civilisation.

And just in proportion as we doubt the transmission of desirable acquired characters, so much the more should we desire to secure that improved conditions of life foster the individual development of each successive generation.

That pathological conditions, innate in the organism, tend to be transmitted, suggests that men should be informed and educated as to the undesirability of parentage on the part of abnormal members of the community.

The widest problems of heredity are raised when we substitute "fraternities" for individuals, or make the transition to social inheritance—the relation between the successive generations of a society.

Thus Sir Francis Galton called attention to the regularity observed in the peculiarities of great populations throughout a series of generations. "The large do not always beget the large, nor the small the small; but yet the observed proportion between the large and the small, in each degree of size and in every quality, hardly varies from one generation to another." A specific average is sustained. This is not because each individual leaves his like behind him, for this is not the case. It is rather due to the fact of a regular regression or deviation which brings the offspring of extraordinary parents in a definite ratio nearer the average of the stock.

"However paradoxical it may appear at first sight, it is theoretically a necessary fact, and one that is clearly confirmed by observation, that the stature of the adult

offspring must on the whole be the more mediocre than the stature of their parents—that is to say, more near to the median stature of the general population." "Each peculiarity in a man is shared by his kinsmen, but *on the average* in a less degree. It is reduced to a definite fraction of its amount, quite independently of what its amount might be. The fraction differs in different orders of kinship, becoming smaller as they are more remote."

Yet it must not be supposed that the value of a good stock is under-estimated by Galton, for he shows how the offspring of two ordinary members of a gifted stock will not regress like the offspring of a couple equal in gifts to the former, but belonging to a poorer stock, above the average of which they have risen.

Yet the fact of regression tells against the full transmission of any signal talent. Children are not likely to differ from mediocrity so widely as their parents. "The more bountifully the parent is gifted by nature, the more rare will be his good fortune if he begets a son who is as richly endowed as himself, and still more so if he has a son who is endowed more largely." But "The law is even-handed; it levies an equal succession-tax on the transmission of badness as of goodness. If it discourages the extravagant hope of a gifted parent that his children will inherit all his powers, it no less discountenances extravagant fears that they will inherit all his weakness and disease."

The study of individual inheritance, as in Galton's *Hereditary Genius*, may tend to develop an aristocratic and justifiable pride of race when a gifted lineage is verifiable for generations. It may lead to despair if the records of family diseases be subjected to investigation.

But the study of social inheritance is at once more democratic and less pessimistic. The nation is a vast fraternity, with an average towards which the noble tend, but to which the offspring of the under-average as surely approximate.

The importance of this consideration may be more readily appreciated if we take an actual case from Professor Karl Pearson's *Grammar of Science.*

"Fathers of a given height have not sons all of a given height, but an array of sons of a mean height different from that of the father and nearer to the mean height of sons in general. Thus take fathers of stature 72 in., the mean height of their sons is 70·8 in., or we have a regression towards the mean of the general population. On the other hand, fathers with a mean height of 66 in. give a group of sons of mean height 68·3 in., or they have progressed towards the mean of the general population of sons. The father with a great excess of the character contributes sons with an excess, but a less excess of it; the father with a great defect of the character contributes sons with a defect, but less defect of it. The general result is a sensible stability of type and variation from generation to generation."

It must be understood, however, that these statistical generalisations are average statements for fraternities, not physiological conclusions relating to individuals. They do not apply to lineages where there has been close and consistent selection. They do not apply to the inheritance of Mendelian "unit characters." Nor do they take sufficient account of the important fact that resemblances are in part due to similar nurture, not wholly to inheritance of similar inborn characters.

It may be useful to keep the term "social heritage" for what is supremely important in mankind, the registration of experience and achievements which is effected by tradition and custom, by institutions and laws, by literature and art. For these bulk largely in the determination of human life.

CHAPTER XX

THE INFLUENCE OF FUNCTION AND ENVIRONMENT

1. The influence of function—2. The influence of surroundings—3. The transmissibility of acquired characters or somatic modifications—4. The importance of nurture—5. The other side of heredity.

1. **The Influence of Function.**—A skilled observer can often discern a man's occupation from his physiognomy, his shoulders, or his hands. In some unhealthy occupations the death-rate is three times that in others. Disuse of such organs as muscles tends to their degeneration, while increased exercise is within certain limits associated with increased development.

Precise illustrations of the influence of function on animals are far from being abundant. Three sample cases may be cited. (1) A Japanese investigator, Shinkishi Hatai, has shown in the case of the white rat that long-continued exercise markedly increases the weight of the heart, kidneys, and liver, on an average to about 20 per cent. He exercised the rats for 90–180 days, which is comparable to a period of 7–14 years in man, for the span of life in the white rat is about three years. (2) Semper and De Varigny found that when freshwater snails were reared in vessels of a shape that allowed them abundant water but very little surface on which to take exercise they developed into dwarf forms. Every precaution was taken to secure abundant food, perfect aeration, and thorough removal of waste-products. De Varigny's experiments were particularly careful and point convincingly to the conclusion that the con-

dition of dwarfing was the restricted area for exercise. (3) The results of physical exercises show that the size and strength of a muscle may be greatly increased by persistent practice. This is well known in the legs of professional dancers, in the powerful wrist of the violinist, and in the arms of the blacksmith. *A force de forger on devient forgeron.*

Even if we could gather many illustrations of the influence of use and disuse on individual animals, we should still have to find out whether the peculiarities or modifications acquired by individuals were in any representative way transmissible to the offspring, or whether any secondary effects of the acquired characters were transmissible, or whether these changes had no effect upon succeeding generations.

It is easy to find hundreds of cases in which the constant characters of animals may be hypothetically interpreted as the result of use or disuse. Is the torpedo-like shape of swift swimmers due to their rapid motion through the water, do burrowing animals necessarily become worm-like, has the giraffe lengthened its neck by stretching it, have hoofs been developed by running on hard ground, are horns responses to butting, are diverse shapes of teeth the results of chewing diverse kinds of food, are cave-animals blind because they have ceased to use their eyes, do the wing bones and muscles of the domesticated duck compare unfavourably with those of the wild duck because the habit of sustained flight has been lost by the former?

To questions of this sort it must be answered that the facts at present known do not afford much support to the theory of the direct origin of adaptations. "It is infinitely easy," Semper says, "to form a fanciful idea as to how this or that may be hypothetically explained, and very little trouble is needed to imagine some process by which hypothetical fundamental causes—equally fanciful—may have led to the result which has been actually observed. But when we try to prove by experiment that this imaginary process of development is indeed the true and inevitable one, much time and

laborious research are indispensable, or we find ourselves wrecked on insurmountable difficulties."

What may be the outcome of further experiments on the effects of use and disuse no one can tell, but as things stand at present there are few adequately precise data in regard to individual modifications due to peculiarities in function, and no quite secure data warranting us in believing that individually acquired functional modifications can be transmitted to the offspring as such or in any representative degree.

In this connection misunderstandings are apt to arise; thus reference is often made to cases like that of the trotting horse. In 1796 its utmost speed was stated at a mile in 2 min. 37 sec.; in 1896 at 2 min. 10 sec. Does it not follow that the trotting horse has been improved by the transmission of the results of systematic training in trotting? It certainly does not follow from the evidence available, which points to the conclusion that the improvement has been due to the selective breeding of the constitutionally swift.

It is sometimes said that years of industry in an occupation like shoemaking result in definite anatomical changes in joints and muscles, and that evidence of the entailment of these modifications may be detected in men whose fathers and grandfathers were shoemakers. If a case like this could be established beyond all criticism it would be of great interest, but no perfectly certain case is known. Where the offspring follow the same occupation as their parents did, the same functional modifications are of course reacquired. But this proves nothing as to transmission.

From one point of view the living body is a great system of correlated chemical processes. Many different lines of chemical change or metabolism go on simultaneously, but on the whole harmoniously. When there is some marked peculiarity of function there is a local predominance of a corresponding metabolism. Thus the strengthening of muscle in a professional dancer's legs implies an exaggeration of that line of metabolism (myogenic) which leads to the production of muscle-substance.

Because of the correlation that exists in the living body there seems to be, as Bohn points out, a tendency for the myogenic metabolism to spread, and the heart-muscle is also strengthened. It is possible that although the germ-cells are unaffected by the strengthening of any particular muscle, they might in the course of time be affected by a persistent exaggeration of myogenic metabolism in the body. This suggests at least an interesting inquiry.

Changes in function that have deeply saturating influences on the individual body may have indirect effects on the germ-cells and thus influence the next generation. But this is a very different matter from the transmission of a particular functional modification. It must also be clearly understood that improvements or disturbances in the function of a mammalian mother with young often have a general strengthening or weakening effect on the offspring.

2. **The Influence of Surroundings.**—In ancient times men saw the threads of their life passing through the hands of three sister Fates—of one who held the distaff, of another who offered flowers, and of a third who bore the abhorred shears of death. In Norseland the young child was visited by three sister Norns, who brought characteristic gifts of past, present, and future, which ruled the life as surely as did the hands of the three Fates. So, too, in days of scientific illumination, we speak of life as determined by the organism's legacy or inheritance, by force of habit or function, and by the influences of external conditions or environment. What the living organism is to begin with, what it does or does not in the course of its life, and what surrounding influences play upon it,—these are the three Fates, the three Norns, the three Factors of Life. Organism, function, and environment are the sides of the biological prism. Thus we try to analyse the light of life. But inheritance in its widest sense is only another name for the organism itself, and function is simply the organism's activity. The organism is real; the environment is real, in it we live and move; function consists of action and reaction between these two realities.

A living animal is almost always either acting upon its surroundings or being acted upon by them, and life is the relation between two variables—a changeful organism and a changeful environment. And since animals do not and cannot live *in vacuo*, they should be thought of in relation to their surroundings. You may kill the body and cut it to pieces, and the result may be interesting, but you have lost the animal just as you lose a picture if you separate figure from figure, and all from the associated landscape or interior. The three Fates are sisters, they are thoroughly intelligible only as a Trinity.

The most certain of all the relations between an organism and its surroundings is the most difficult to express. We see a small whirlpool on a river, remaining for days or weeks apparently constant, with the water circling round unceasingly, bearing the same flotsam of leaves and twigs. But though the eddy seems the same for many days, it is always changing, currents are flowing in and out; it is the constancy of the stream and its bed which produces the apparent constancy of the whirlpool. So, in some measure, is it with an animal in relation to its surroundings. Streams of matter and energy are continually passing in and out. Though we cannot see it with our eyes, the organism is indeed a whirlpool. It is ever being unmade and remade, and owes much of its apparent constancy to the fact that the conditions in which it lives—the currents of its stream—are within certain limits uniform.

And as we cannot understand the material aspects of an animal's life without considering the streams of matter and energy which pass in and out, neither can we understand its higher life apart from its surroundings. To attempt a natural history of isolated animals, whether alive or dead, is like trying to study man apart from society.

At present, however, we have to do with the relation between external and internal changes. In a smithy we see a bar of hot iron being hammered into useful form. Around a great anvil are four smiths with their

hammers. Each smites in his own fashion as the bar passes under his grasp. The first hammer falls, and while the bar is still quivering like a living thing it receives another blow. This is repeated many times till the thing of use is perfected. By force of smiting one becomes a smith, and by dint of blows the bar of iron becomes an anchor. So it is with the organism. In its youth especially, it comes under the influence of nature's hammers; it may become fitter for life, or it may be battered out of existence altogether. Let us try to analyse the various environmental factors.

(*a*) *Pressures.*—First we may consider those lateral and vertical pressures due to air or water currents and to the gentle but potent force of gravity. The shriek of the wind as it prunes the trees, the swish of the water as it moulds the sponges and water-leaves, illustrate the tunes of those pressure-hammers. Under artificial pressure the shape of an embryo may be altered; even the division of the egg is affected by gravity; water currents affect the growth of corals. The influence of want of room must also be noticed, for, as we have mentioned, dwarf broods of the water-snail Limnæa may be produced in vessels which do not allow them sufficient exercise ground on the surface. In the cases of the freshwater snails, the influence of restricted space was separated off from associated abnormal conditions, such as the accumulation of poisonous waste-product; but this is not always practicable.

(*b*) *Chemical Influences.*—Quieter, but more potent, are the chemical influences which damp or fan the fire of life, which corrode the skin or drug the system, which fatten or starve, depress or stimulate. Along with these we must include that most important factor—food.

When a lighted piece of tinder is placed in a vessel full of oxygen it burns more actively. Similarly, superabundance of oxygen makes insects jump, makes the simplest animals more agile, and causes the "phosphorescent" lights of luminous insects to glow more brightly; and young creatures usually develop more or less rapidly according as the aeration is abundant or deficient. The

most active animals—birds and insects—live in the air and have much air in their bodies; sluggish animals often live where oxygen is scarce; changes in the quality of the atmosphere may have been of importance in the historical evolution of animals. Fresh air influences the pitch of human life, and lung diseases increase in direct ratio to the amount of crowded indoor labour in an area. It is obvious that in part this simply means that the

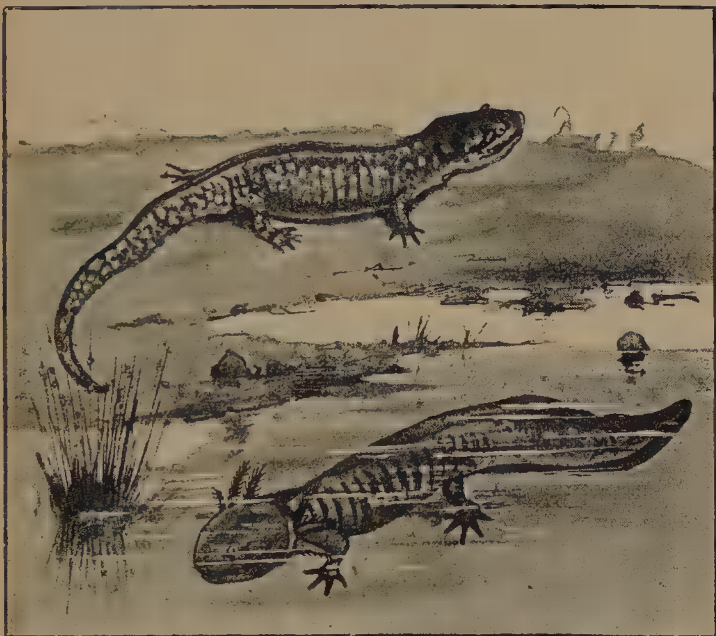


FIG. 119.—AXOLOTL (IN THE WATER) AND AMBLYSTOMA (ON THE LAND).

opportunities for infection with the tubercle bacillus are greatly increased by crowding, but there is a positive tonic value in fresh air.

By keeping tadpoles in sub-aquatic conditions the usual duration of the gilled stage may be prolonged for two or three years, and giants are thus produced. The well-known story of the Axolotl and the Amblystoma may be recalled. These two newt-like Amphibians differ slightly in shape, and in this, that the Axolotl retains

its gills after it has developed lungs, while the Amblystoma loses them. Both forms may reproduce, and they were originally referred to different genera. But some Axolotls which had been kept with scant water in the *Jardin des Plantes* in Paris turned into the Amblystoma form; the two forms are different phases of the same animal. It was a natural inference that the Axolotls were those which had remained or had been kept in the water, the Amblystoma forms were those which got ashore. That the matter is more complex than was previously supposed is shown by the fact that both kinds may be found in the water of the same lake and the metamorphosis may take place in the water as well as on the shore. It seems that the Axolotls retain certain larval characters although they have reached their full size and have become reproductive. The same phenomenon occurs in other types, among Amphibians and elsewhere, and is known as pædogenesis. It is a special case of a possibility that is often open to animals with a markedly punctuated life-history—the possibility of lengthening out one chapter and shortening another. It is quite likely that some species have arisen in this way, *e.g.* as persistently juvenile or as prematurely senile forms.

Another influence of the chemical environment is that

FIG. 120.—SIDE VIEW OF MALE *Artemia salina* (ENLARGED). (From Chambers's *Encyclop.*)

of prompting variations. This is probably illustrated by the story of the brine-shrimps (*Artemia*), first told by the Russian naturalist Schmankewitsch. There is a form called *A. salina* (see figs. 120 and 121) which has well-developed bristly tail-lobes, and Schmankewitsch found that concentration of the water led to its being replaced by another form (we can hardly say species), called *A.*

milhausenii, which has not caudal lobes. He also found that if the forms without caudal lobes were kept in brine which was gradually diluted, these were replaced by those of the *A. salina* type. The two forms are connected by intermediate stages, and it seems that *Artemia salina* is a species very variable as regards the tail and caudal bristles. It seems, then, that what the environment did in this case was to induce variability and to shunt the variation in one direction or the other.

FIG. 121.—TAIL-LOBES OF *Artemia salina* (TO THE LEFT) AND OF *Artemia milhausenii* (TO THE RIGHT); BETWEEN THESE FOUR INTERMEDIATE STAGES.

(From Chambers's *Encyclop.*; after Schmankewitsch.)

Many interesting experiments have been made on the effect of chemical reagents on cells, a promising path of discovery which has not yet been adequately appreciated by medical investigators. By slight changes the form of a cell and its predominant phase of activity may be entirely changed. This is surely an important consideration, when we remember that it was in single cells that life began, and that all multicellular organisms reproduced in the ordinary way begin their individual life as single cells. Even Weismann agreed with Spencer's conclusion that "the direct action of the medium was the *primordial* factor of organic evolution."

To Claude Bernard, the main problem of evolution seemed to be concerned with variations in nutrition: "L'évolution, c'est l'ensemble constant de ces alternatives de la nutrition; c'est la nutrition considerée dans sa réalité, embrassée d'un coup d'œil à travers le temps." John Hunter and others have shown how the walls of the

stomach of gulls and other birds may be experimentally altered by change of diet, and the same is seen in nature when the Herring Gull changes from its summer diet of grain to its winter diet of fish. The colours of birds' feathers, as in canaries and parrots, are affected by their food. Mr. Beebe, Curator of birds in the New York Zoological Gardens, has shown that some birds, such as the bobolink, may be dieted so that they keep their breeding plumage throughout the year and will sing their spring song in mid-winter. This is biological magic.

Very striking, too, are Prof. Child's experiments on the effect of altered diet on Planarian worms. Thus a diet of freshwater mussels, for some unknown reason, depresses the vitality, *i.e.* lessens the rate of metabolism and the power of resistance. The stock becomes senescent, and if the diet be continued for several generations there is an aggravation of senescence, for the individuals begin to be "born old." The effect of the mussel diet is cumulative.

When food is abundant, assimilation active, and income above expenditure, the animal grows, and at the limit of growth in lower animals asexual multiplication occurs. Checked nutrition, on the other hand, favours the higher or sexual mode of multiplication. Thus the gardener prunes the roots of a plant to get better flowers or reproductive leaves. The plant-lice or Aphides, which infest our pear-trees and rose-bushes, well illustrate the combined influence of food and warmth. All through the summer, when food is abundant and the warmth pleasant, the Aphides enjoy prosperity, and multiply rapidly. For an Aphis may bring forth young every few hours for days together, so rapidly that if all the offspring of a mother Aphis survived, and multiplied as she did, there would in the course of a year be a progeny which would weigh down 500,000,000 stout men. But all through the summer these Aphides are wholly female, and therefore wholly parthenogenetic; no males occur. In autumn, however, when hard times set in, when food is scarcer, and the weather colder, males are born, parthenogenesis ceases, ordinary sexual reproduction recurs. Moreover, if the Aphides be kept in the artificial summer

of a greenhouse, as has been done for four years, the parthenogenesis continues without break, no males being born to enjoy the comforts of that environment.

Periods of fasting occur in the life-history of many animals, and these are very momentous and progressive periods in the lives of some, for the tadpole fasts before it becomes a frog, and the chrysalis before it becomes a butterfly. Lack of food, however, may stunt development, as we see every day in the streets of our towns.

(*c*) *Radiant Energy.*—Of the forms of radiant energy which play upon the organism, we need take account only of heat and light, for of electrical and magnetic influence the few strange facts that we know do not make us much wiser.

We know that increased warmth hastens motion, the development of embryos, and the advent of sexual maturity. An Infusorian (*Stylonichia*) studied by Maupas was seen to divide once a day at a temperature of 7°–10° C., twice at 10°–15°, thrice at 15°–20°, four times at 20°–24°, five times at 24°–27° C. At the last temperature one Infusorian became in four days the ancestor of a million, in six days of a billion, in seven days and a half of 100 billions, weighing 100 kilogrammes. By consummately patient experiments, Dallinger was able to educate Monads which lived normally at a temperature of 65° Fahr., until they could flourish at 158° Fahr.

Cold has generally a reverse action, checking activity, producing coma and lifelessness, diminishing the rate of development, tending to produce dwarf or larva-like forms. Here we are dealing with direct physiological effects, and the mode of operation is in part clear. Cold lessens the rate of certain chemical processes (as in the inorganic domain); the formation of nuclein bodies within the cell is slowed; this puts a drag on cell-division and growth. The dense population of small animals in boreal seas, for some types denser than in the tropics, has been explained by Loeb as due to this slowing of life. There are more generations living at the same time. It would be interesting if we had data as to the rate of growth in the eternal winter of the Deep Sea.

In many cases the heat or cold is influential simply as what we may call a trigger-puller. It induces certain predispositions to express themselves, as is well illustrated by seasonal changes. The variable hare (*Lepus variabilis*), the stoat (*Putorius ermineus*), the ptarmigan (*Lagopus mutus*), and some other animals turn white every year when the winter approaches, and what the cold does is to set a-going a periodic change which has been engrained in the constitution in the course of ages. We may think of the environment in such cases as a liberating stimulus. Many cases are known where a

FIG. 122.—SEASONAL DIMORPHISM OF *Papilio ajax*; TO THE LEFT THE WINTER FORM (VARIETY *telamonides*), TO THE RIGHT THE SUMMER FORM (VARIETY *marcellus*).

(From Chambers's *Encyclop.*; after Weismann.)

butterfly produces in a year more than one brood, of which the winter forms are so different from those born in summer that they have often been described as different species. It is possible that this is a reminiscence of past climatic changes, such as those of the Ice Ages, as the result of which a species became split up into two varieties. Thus *Araschnia levana* and *Araschnia prorsa* are respectively the winter and summer forms of one species. In the glacial epoch there was perhaps only *A. levana*, the winter form; the change of climate has perhaps evolved the summer variety *A. prorsa*. Both Weismann and Edwards have succeeded, by artificial

cold, in making the pupæ which should become the summer *A. prorsa* develop into the winter *A. levana.* Nor can we forget the seasonal moulting and the subsequent change of the plumage in birds, so marked in the case of the ptarmigan, which moults three times in the year. In the puffins even the bill is moulted and appears very different at different seasons.

Light is very healthful, but it is not easy to explain its precise influence. Our pulses beat faster when we go out into the sunlight. Green plants depend as much on the sunlight as on the soil and the air. It is possible that light has a direct influence on the formation of some

FIG. 123.—SEASONAL CHANGES OF THE BILL IN THE PUFFIN (*Fratercula arctica*); TO THE LEFT THE SPRING FORM, TO THE RIGHT THE WINTER FORM, BOTH ADULT MALES.

(After Bureau.)

animal pigments, as it seems to have in the development of chlorophyll. We know, from Poulton's experiments, that the light reflected from coloured bodies influences the colouring of caterpillars and pupæ, but this influence seems to be subtle and indirect, operating through the nervous system. In the dark caves of Dalmatia, Carniola, and Carinthia there lives a well-known salamander called Proteus, with a wan white skin slightly flushed by the blood. Its skin, as Gadow said, is like a photographic plate, for if the creature be exposed to light it becomes covered with dark spots and eventually quite black. If eggs are laid by individuals kept in the light the newly hatched larvæ are dark. This is probably due to the direct influence of the light on the eggs—even before

they are laid. But there is room here for further inquiry. Ogneff found that Axolotls kept in darkness, and starved, lost their black pigment-cells, both inside and outside.

It has been shown by Ogneff that goldfishes kept in the dark for three years become totally blind, the essential parts of the retina (the image-forming portion of the eye) disappearing. Thus a fish imprisoned in a cave might become blind through the influence of darkness and disuse on the individuals. If the dwindling of the eye was more pronounced in the second and still more in the third generation, the case would show the transmission of an individually acquired peculiarity—an environmental modification. It is more probable, however, that the blindness of cave animals is due to a germinal variation. It is very interesting to notice Loeb's result that while a certain amount of blindness can be readily induced in embryos of a fish called *Fundulus heteroclitus* (*e.g.* by fertilising the ova with spermatozoa from another fish (*Menidia*), or by adding a little potassium cyanide to the water containing the developing ova, or by exposing the newly fertilised ova to low temperature for some hours), *lack of light does not influence the development of the eyes.*

One case of the influence of light seems very instructive. It is well known that flat fishes like flounders, plaice, and soles lie or swim in adult life on one side. This lower side is unpigmented; the upper side bears black and yellow pigment-containing cells. In part, probably, this is the outcome of a process of sifting continued for ages. For coloration is a very variable character, and it is economical, to say the least, to have no pigment on the surface which is not seen. But it is open to question whether the characteristic is so advantageously protective as is usually imagined: thus the coloured upper side in soles is very often covered with a layer of sand. Soles come out most at night, many live at depths at which differences of colour are probably indistinct. In shallower water the advantage is likely to be greater, though the white under-side slightly exposed as the fish rises from the bottom may attract attention disadvan-

tageously. It may be asked whether the absence of pigment is not in part the direct physiological result of the relative absence of the light-stimulus in each individual case.

The beginning of an answer is to be found in Mr. J. T. Cunningham's crucial experiment of illuminating the under-sides of young flounders. Out of thirteen whose under-sides were thus illuminated by a mirror for about four months, only three failed to develop black and yellow colour-cells on the skin of the under-sides. It is therefore likely that the normal whiteness of the under-sides depends in part on the conditions of individual nurture, to the fact that in natural conditions little light can fall on them, for they are generally in contact with the ground.

(*d*) *Animate Surroundings.*—We have given a few instances showing how mechanical or molar pressures, chemical and nutritive influences, and the subtler physical energies of heat and light, affect organisms. There is a fourth set of environmental factors—the direct influence of organism upon organism. In a previous chapter we spoke of the indirect influences different kinds of organisms exert on one another, and these are most important, but there are also results of direct contact.

Much in the same way as insects produce galls on plants, so sea-spiders (Pycnogonidæ) affect hydroids, a crab deforms a coral, a little "worm" (*Myzostoma*) makes galls on Crinoids. Certain degenerate Crustaceans parasitic on crabs destroy the reproductive organs of their hosts, and some internal parasites produce slight modifications of structure. Interesting also are the shelters or domatia of some plants, within which insects and mites find homes.

Looking backwards, we recognise that environment may influence the organism in varying degrees. There may be direct results, rapid parries after thrusts, or the results may be indirect. Some animals are more susceptible and more plastic than others. Young organisms, such as caterpillars and tadpoles, are more completely in the grasp of their environment than are the adults.

Thus Treviranus, who believed very strongly in the influence of surroundings, distinguished two periods of *vita minima*—in youth and in old age—during which external conditions press heavily, from the period of *vita maxima*—in adult life—when the organism is more free. To some kinds of influence, *e.g.* mechanical pressures, passive and sedentary organisms such as sponges, corals, shell-fish, and plants, are more susceptible than are those of active life.

The human organism, like any other, may be modified by its environment. Those external influences which touch body and mind are to us the more important, since we have them to some extent within our own hands, and because our lives are relatively long. Even if the changes thus wrought upon parents are not transmissible, it is to some extent possible for us to secure that our children grow up open to influences known to be beneficial, sheltered from forces known to be injurious.

As the influence of surroundings is especially potent on young things—such as caterpillars and tadpoles—all care should be taken of the young child's environment during the earliest months and years, when the grip that externals have is great.[1]

As passive organisms are more in the thrall of their surroundings than are the more active, we may emphasise the importance of beauty in the home, that the organism may be saturated with healthful influence during the periods in which it is most susceptible. The manifold endeavours which are made to improve and beautify human surroundings are justified not only by their results—ideally stated in Emerson's well-known poem of "Art,"—but by the biological facts on which they more or less unconsciously depend. There would be more progress and less invidious comparison of ameliorative schemes if we realised more vividly that the Fates are three. Though it is not easy to appreciate the three sides of a prism at once, of what value is liberty on an ash-heap, or equality in a hell, or fraternity among

[1] Cf. Matthew Arnold's poem, "The Future," and Walt Whitman's "Assimilations."

an over-populated community of weaklings? Organism, function, and environment must evolve together.

3. **The Transmissibility of Acquired Characters or Somatic Modifications.**—When animals of the same kind are carefully compared they usually show individual peculiarities, which may be conveniently called "the observed differences." When we begin to sift out these "observed differences" we find that some may be due to differences of age and sex, and these can be kept by

FIG. 124.—HALF-LOP RABBIT, AN ABNORMAL VARIATION, WHICH BY ARTIFICIAL SELECTION HAS BECOME CONSTANT IN A BREED. (From Darwin.)

themselves. Others are the direct results of peculiarities in the individual's surroundings, nutrition, and habits, and these are called "modifications," or "somatic modifications," or "acquired characters." They may be defined as *structural changes in the body of the organism directly induced in the individual lifetime by peculiarities in function or environment, which transcend the limit of organic elasticity and thus persist after the inducing conditions have ceased to operate.* Now, when we subtract from the total of *observed differences* between members

of the same species all those that are due to age and sex, and all those that can be shown to be *modifications*, the remainder consists of inborn or germinal *variations*, endogenous not exogenous in origin. We are sure that many variations, both large and small, are transmissible from the organisms that first show them to their descendants or to a certain proportion of their descendants. In regard to the transmissibility of modifications, however, the absence of convincing evidence has forced most naturalists into a position of scepticism. This scepticism is not strictly modern—we find expressions of it on the part of Kant, His, Pflüger, Prichard, and others. A few sentences from Galton (1875), whose far-sightedness has been insufficiently recognised, may be quoted :

"The inheritance of characters acquired during the lifetime of the parents includes much questionable evidence, usually difficult of verification. We might almost reserve our belief that the structural cells can react on the sexual elements at all, and we may be confident that at the most they do so in a very faint degree—in other words, that acquired modifications are barely, if at all, *inherited* in the correct sense of that word."

But Weismann brought the discussion to a climax by altogether denying the transmissibility of acquired characters. Weismann's reasons for maintaining that no acquired characters are transmissible are twofold,—first, because the evidence in favour of such transmission is in the main anecdotal and is never cogent ; second because the "germ-plasm," early set apart in the development of the body, is from the nature of the case likely to remain but little affected by the vicissitudes which beset the body. Weismann was quite clear that bodily modifications, due to peculiarities of function and environment, might be very important for the individual. What seemed to him unlikely was that their influence could spread through the body so as to affect the reproductive cells in a specific and representative way. Unless they do so, they cannot be transmitted, and evidence of this transmission is conspicuous by its absence.

The precise point of the discussion as to the trans-

mission of somatic modifications (badly called "the inheritance of acquired characters") may be stated thus: Does a structural or metabolic change directly induced in the body of an individual organism as the result of some peculiarity in function (use and disuse) or in environment and nurture generally, ever affect the germ-plasm in the reproductive organs in such a specific or representative way that the offspring will thereby, though not subjected to the nurtural peculiarity in question, exhibit the same modification that the parent acquired, or even an approximation towards it?

It is easy to *interpret* evolutionary change on the Lamarckian assumption that somatic modifications are transmissible, but it is difficult to find any convincing evidence for the assumption. It is admitted that somatic modifications may have secondary effects on the germ-cells and on the offspring (especially in the case of the viviparous mammals), but that is not proving the transmissibility of particular modifications. It is probable that long-continued, deeply saturating environmental and functional peculiarities may produce substances that enter into the cytoplasm of the germ-cell or into the embryonic body (*e.g.* the mammalian fœtus or the seed of a flowering plant), but there is as yet no convincing evidence that the resulting changes grip the constitution permanently. It is not impossible that particular modifications of an incisive sort may liberate very specific chemical substances, like hormones, and that these may be carried to the germ-cells and accumulate there with subsequent formative (morphogenetic) influence, but facts are required to substantiate this hypothesis. As to diseases, so often referred to in this connection, "when we come to understand that pre-natal infection is not inheritance, that inheritance of a predisposition to a disease is not inheritance of the disease, that the general weakening of the offspring through disease in the parent is a very different matter from the transmission of a specific disease, we are almost irresistibly led to the conclusion that in the sense in which the word "inherited" is used in biology there are no inherited diseases. What

does seem to be inherited, however, is a defectiveness or disturbance or degeneracy of the germ-plasm which may find one expression in the parent and another in the offspring, or the same in both."[1]

The student should recognise that the long-drawn-out discussion on the transmission of somatic modifications can only be settled by the critical accumulation of facts. There should be no attempt to close it or to dogmatise about it. As Prof. E. B. Wilson has wisely said: "In the present defective state of our knowledge we may well grant that there may be many a thing between germ-cell and body that is not yet dreamed of in our biological philosophy."

4. **The Importance of Nurture.**—If individually acquired modifications due to peculiarities of function and environment are not transmissible, it does not appear at first sight that nurture can be of much evolutionary importance to the race. This is confirmed as regards man by the statistical inquiries which have led Prof. Karl Pearson and his collaborators in the Galton Laboratory to the important conclusion that the results of changes in nurture are of relatively small importance compared with the results of variation in the physique, the mentality, and the habits of parents,—that "the degree of dependence of the child on the characters of its parentage is ten times as intense as its degree of dependence on the character of its home or uprearing." "It is five to ten times as profitable for a child to be born of parents of sound physique and of brisk, orderly mentality, as for a child to be born and nurtured in a good physical environment." But while there is no doubt as to the fundamental importance of the inherited nature, there is also importance in nurture.

(1) Since nature and nurture are both indispensable, there is no *antithesis*. Some creatures are indeed so strong that changes of nurture do not seem to matter very much, so long as the essential conditions of life are not interfered with; in many other cases, however, the

[1] See the author's *Darwinism and Human Life*, revised edition. Melrose, London, 1916.

success of the development depends on the availability of an appropriate nurture, the details of which are often very precise. In his work on *The Mechanism of Mendelian Heredity* (1915), Prof. T. H. Morgan emphasises the mutual dependence of nature and nurture : a "character is the product of a number of genetic factors and of environmental conditions"; "every character is the realised result of the reaction of hereditary factors with each other and with their environment"; or again, "it is a commonplace that the environment is essential for the development of any trait, and that traits may differ according to the environment in which they develop."

While the strength of an (inherited) individuality may be such that it expresses itself almost in the face of inappropriate nurture, there is a minimum nurture necessary if there is to be any development at all; and the conditions of nurture determine whether the expression of the inheritance is to be full or partial, abundant or stunted, or, it may be, as regards a particular feature, absent altogether.

Gudernatsch has shown that in tadpoles fed on thyroid there is differentiation without growth, while in tadpoles fed on thymus and spleen there is growth without differentiation. A character known to be part of the inheritance may remain entirely unexpressed in the individual development because certain environmental conditions are lacking, yet the heritable character may be handed on all the same. Thus fruit-flies (Drosophila) of a Mendelian race with a peculiar abnormality may appear perfectly normal if raised in a dry bottle, but the presence within them of the "factor" for abnormal may be demonstrated by rearing their offspring in a wet bottle.

A diagrammatic illustration concerns the red Chinese primrose (*Primula sinensis rubra*). Reared at 15°–20° C. it has red flowers; reared at 30°–35° C., with moisture and shade, the same plants have pure white flowers like those of *Primula sinensis alba*, which always has white flowers. The development of colour in the red Chinese primrose depends on its nurture.

Take another illustration from the fruit-fly. There

is a mutant stock that produces supernumerary legs, a considerable percentage in winter, few or none in summer. Miss Hoge finds that when the flies are kept in an ice-chest at a temperature of about 10° C., a high percentage of flies with supernumerary legs occurs. In a hot climate there would be no evidence that the peculiarity was part of the inheritance; in a cold region it would be obvious. This shows that the expression of the inheritance as regards a particular character sometimes depends on nurture.

(2) While some developing organisms are strikingly indifferent to changes in their environment, there are others which respond sensitively, sometimes in a startling way, to changes which do not seem very drastic. MacDougal's experiments[1] of injecting solutions of sugar and of compounds of calcium, potassium, and zinc into the developing ovaries of an Evening Primrose resulted in a small percentage of notably atypical individuals, which bred true to the third generation. The chemical reagents introduced were not very different from those which might occur naturally in the sap of the plant. Among the changes induced there were not only losses and augmentations of what was previously present, there were distinct novelties which maintained their distinctness when crossed with the parental strains.

Loeb has recently shown that it is very easy to produce a percentage of fish-embryos (*Fundulus*) with defective eyes by adding a very minute quantity of potassium cyanide to the water or by exposing the developing eggs to low temperature. That is to say, relatively slight environmental changes may so alter the constitution of the developing embryo that a leap is taken in the direction of blindness. Similarly Stockard has shown for the same fish that the addition of a very minute quantity of magnesium salt to the water induces in a large number of embryos the development of a single Cyclopean eye in place of the normal two eyes.

Such cases are to be borne in mind in connection with

[1] In lecture on "The Direct Influence of Environment" in *Fifty Years of Darwinism* (1909).

man and mammals where even slight extrinsic or exogenous changes in the blood of the mother may affect the development of the unborn offspring living in intimate symbiosis with her. It is very important to realise the difficulty of distinguishing between what is due to inherited nature and what is due to some peculiarity in ante-natal nurture.

The effect of negative nurture on the individual is sometimes very remarkable. It is well known that certain simple worms (Planarians) can be starved for months without fatal effects. They become smaller and smaller, living on their own internal resources. Some of their cells disappear altogether and others are greatly reduced in size. This is an old story, but Prof. Child has recently shown that the reduction in size is associated with a remarkable rejuvenescence, and that the vital processes are quickened. The starveling becomes young again—surely a quaint biological justification of asceticism. Many similar facts are given in Child's recently published book on *Senescence and Rejuvenescence*.

And what is true of nutrition is true of other factors in nurture; they alter the punctuation of the life-cycle. A herring's egg in the sea hatches in about a week; put it in a refrigerator, and the development is slowed down so that the egg takes fifty days to hatch.

(3) Without assuming that a peculiarity of the body acquired as the direct result of a peculiarity in nurture can be as such or in any representative degree entailed on the offspring, of which there is no convincing proof, we may recognise that nurture may be of considerable importance to the race in indirect ways. The modification may give the individual a life of conspicuous success or failure, which may result in a subsequent increase or decrease in the numbers of the type which is modified, thus obviously working for both good and ill to the race. Vigour acquired by open-air exercise gives a man resisting power against infection; it may keep bad constitutions alive; it may also keep good constitutions from being gratuitously weakened. Reduction of the likelihood of infection will also work both ways. Moreover, organisms

are more or less active agents, and changes in environment offer opportunities for effort, *e.g.* for trying to find a new haunt.

It has often been pointed out that an individually acquired modification may serve as a life-saving screen until an innate variation with similar result has time to establish itself. Thus artificial immunity may be a useful temporary modification until natural immunity arrives as a germinal variation—if it does so arrive.

In the case of mammals the unborn offspring may be seriously handicapped by the ill-nourished, over-strained, or poisoned state of the maternal body. There is no transmission of acquired characters in the technical sense, but there is ante-natal deterioration and arrestment of the offspring as the result of abnormal nurture on the parent's part. Some evidence exists which goes to show that deeply saturating parental modifications, such as the results of poisoning, may affect the germ-cells themselves. The influence very probably affects the cytoplasm, rather than the chromosomes.

There is little likelihood that we are at an end of the question as to the influences of modifications (nurture-effects) on inheritance, and a useful hint of the subtlety of the problem may be got from a brief consideration of the most important British investigation on the subject—Dr. Agar's study of a water-flea (Simocephalus)—a little crustacean with two valves. Under certain nutritive conditions the crustaceans acquired a peculiar reversal of their shell-valves, doubtless as the result of altered metabolism. After the eggs had appeared and grown in the ovary the animals were restored to normal conditions. In due time the eggs developed into forms with reflexed shell-valves such as their parents had acquired. Later on, however, when the parents laid again, the abnormal effect was seen only to a very slight degree, and in a third brood it had dwindled away. The probability is that the abnormal nurture resulted not in any disturbance of the inheritance, but in the formation of some peculiar non-living metabolic product, which was included in the cytoplasm of the egg, passed passively into the body

which developed from the egg, and there produced on the body of the offspring the same effect as it originally produced on the body of the parent which acquired the character in question.

Bordage made some interesting observations on European peach trees transported to Réunion. As has been noticed in similar cases, they dropped their deciduous habit and became—some took twenty years—evergreen. The individual constitution was altered. Still more interesting was the fact that when seeds of these pseudo-evergreens were sown in certain mountainous districts with a considerable amount of frost, they produced young peach trees which were also evergreen. European seeds sown in similar places produced ordinary deciduous trees. It is probable that the apparent inheritance in the case of the peach trees was the result of an influence on the body of the seed before it was separated from the parent. A similar result in mammals may be readily confused with inheritance.

(4) There is an increasing body of facts pointing to the conclusion that changes in nurture may serve as variational stimuli, that is to say that they may affect the germ-cells through the parent, so that a variation occurs in the offspring. Thus Prof. Tower subjected potato-beetles at a certain stage of their development to unusual conditions of temperature and humidity. The body of the beetles exhibited no modification, and that was not to be expected. But in a number of cases the offspring of these beetles showed remarkable changes in colour and markings, and even in minute details of structure. And there was no reversion to the parental condition. It looks as if a peculiarity in the environment might serve as a liberating stimulus to variability.

In this connection it should be borne in mind that much may depend upon the nurtural reception that a natural variation meets with. Unless the nurture evolve progressively along with the nature, *in mankind especially*, many new departures may be blocked at the outset, many promising variations may be born only to die.

On no account whatsoever are we to countenance, if

we can help it, spoiling good stock by bad; but it is a dubious inference that the bad is hopeless. It may often be that it is not so bad as it looks. In her interesting study *Environment and Efficiency*,[1] Miss Mary Horner Thomson tells of her study of 265 children, mostly of "the lowest class" (Class A, fourth below the poverty level!), who had been sent to institutions and trained. She found that 192 (72 per cent.) turned out well; that 44 (16 per cent.) were doubtful; and that only 29 (less than 11 per cent.) were unsatisfactory, and of these 13 were defectives. These figures, which should be checked and multiplied, afford some evidence of the controllability of life.

We have given in the above paragraphs illustrations of a number of facts: that nurture is important as a condition of normal development, that on its richness in liberating stimuli the degree of development in part depends, that even a slight change in nurture may mean a great deal, that in mammals especially it is not always easy to distinguish what is in the strict sense inherited from what is due to ante-natal nurture, that nurtural effects though not transmissible may be in several ways of indirect racial importance. It has also been pointed out that there are some facts suggesting the theory that peculiarities of nurture may act as variational stimuli —tending to the emergence of the new.

It would be quite fallacious to argue from any of the illustrations given to man, but perhaps enough has been said to suggest the undesirability of losing faith too utterly in the potency of nurture in shaping the individual life. Of the danger of arguing from one case to another, an interesting illustration may be found in experiments concerning the influence of alcohol. D. D. Whitney studied the effect of minute traces of alcohol in the water in which Rotifers or wheel animalcules were kept. The result was a decrease in reproductive power and a weakening in the power of resistance to deleterious influences. Twenty-eight generations were studied and the evil

[1] Longmans, 1912.

effects of the alcohol were proved. But from the 11th to the 22nd generation at least it was found that removal of the alcohol was followed by rapid individual recovery, and that the grandchildren showed none of the defects caused by alcohol in their grandparents.

Quite on the other side, however, are the experiments of Stockard, who subjected male guinea-pigs for three years to vapours of alcohol, which does not spoil their digestion, and found that an alcoholised male guinea-pig almost invariably begets defective offspring even when mated with a vigorous normal female. The effects were manifest in the second generation also. The poison injures the cells and tissues of the body, the germ-cells as well as other cells, and the offspring derived from the weakened or affected germ-cells have all the cells of their bodies defective.

In estimating the importance of nurture for the individual we must think of its rôle in the developing human mind. Many biologists and psychologists are agreed in the conclusion that our mind is in large measure a social product. Thus Prof. G. H. Parker writes: "Our intellectual outfit comes to us more in the nature of a social contribution than an organic one." In short, while our mental capacity is primarily determined by heredity, it can be encouraged and augmented, or inhibited and depressed, within wide limits, by nurture.

Especially as regards the mind do we feel that while the inheritance is the seed-corn, "nurture" is the soil and the sunshine, the wind and the rain. Nurture can create nothing, but without it the buds that are there may fail to open or to unfold freely or to blossom. We cannot make a silk purse out of a sow's ear, but by trading with our talent we may make it two, peradventure five talents.

5. **The Other Side of Heredity.**—The past lives on in the present, that is what is meant by heredity. The Hapsburg lip asserts itself after four centuries; night-blindness lingers in the Nougaret lineage since 1637; and having all the fingers thumbs (brachydactylism) has been known to persist for six generations. There is an inexorableness in the transmission of all sorts of inborn

peculiarities (except sterility of course), not only to the third and fourth generation, but far further. Sometimes it is a trivial feature like a shock of white hair; sometimes it is a deadly vice of blood; sometimes it is all bodily, leaving the spirit unblemished, as in certain cripples; sometimes it is a blot on the brain that affects the character now in this way and again in that, but always perniciously. There is no gainsaying the fatalistic impression that the study of heredity forces upon us, and since heredity is the relation of organic or genetic continuity between successive generations, there can be no other side to it. Yet our phrase "The Other Side of Heredity" may usefully serve to indicate that there is another side to the inevitable reappearance of an evil past in the present, another side to the inexorable transmission of defects and weakness, another side to the lien that ancestry has over us.

It should be remembered (1) that the hereditary relation secures the entailment of all manner of wholesome human qualities; (2) that there is continual variability or creativeness which affords new raw material for progress; (3) that the quality of the nurture (largely in our hands) determines the degree to which the buds of good qualities in our inheritance may be made to unfold, and the buds of bad qualities may be kept more or less dormant; (4) that there is an undeniable moulding power in changes of function and environment, and though the resulting modifications do not seem to be transmissible as such, they can be reimpressed, if desirable, on each successive generation; and (5) that in our social heritage, which is as supreme as our natural inheritance is fundamental, there are ever-widening opportunities for transcending the trammels of protoplasm. Wherefore, *Sursum corda*—lift up your hearts!

CHAPTER XXI

THE EVOLUTION OF EVOLUTION THEORIES

1. Early Greek philosophers—2. Aristotle—3. Lucretius—4. Evolutionists before Darwin—5. Three old masters : Buffon, Erasmus Darwin, Lamarck—6. Charles Darwin—7. Darwin's fellow-workers—8. Steps of progress since Darwin's day and summary of evolution theories.

The conception of evolution is no modern idea, it is the human idea of history expanded to cover the whole world. The extension of the idea was gradual, as men felt the need of extending it ; and we sometimes find the same man believing in the eternal permanence of one set of phenomena, in the creation of others, in the evolution of others. Thus he may maintain that human institutions have been evolved ; that man was created ; and that life is eternal. Or another may maintain that matter and motion are eternal ; that life was created ; and that the rest has been evolved.

1. **Early Greek Philosophers.**—Though Zeller has written on the "Grecian predecessors of Darwin," most of the wise men of Greece before Aristotle were philosophers, not naturalists, and we are apt to read modern ideas into their words. They thought, indeed, as we are thinking, about the visible universe, and some of them believed it to be, as we do, the result of a process ; but here in most cases ends the resemblance between their thought and ours.

Thus when Anaximander spoke of a fish-like stage in the past history of man, this was no prophecy of the modern idea that a fish-like form was one of the far-off ancestors of backboned animals; it was only a fancy

invented to get over a difficulty connected with the infancy of the first human being.

Or, when we read that several of these sages reduced the world to one element, the ether, we do the progress of knowledge injustice if we say that men are simply returning to this after more than two thousand years. For that conception of the ether which is characteristic of modern physical science has been, or is being, slowly attained by precise and patient analysis, whereas the ancient conception was reached by metaphysical speculation.

When we read that Empedocles sought to explain the world as the result of two principles—love and hate—working on the four elements, we may, if we are so inclined, call these principles "attractive and repulsive forces"; we may recognise in them the altruistic and individualistic factors in organic evolution, and what not; but Empedocles was a poetic philosopher, no far-sighted prophet of evolution.

But the student cannot afford to overlook the lesson which Democritus first clearly taught, that we do not account for any result until we find out the natural conditions which bring it about. The scientific question is how any given structure came to be as it is, and this is not answered by discovering its utility. It is advantageous for a root to have a root-cap, but we wish to know how the cap comes to be there. It is obvious that the antlers of a stag are useful weapons, but we must inquire as precisely as possible how they first appeared and still grow.

2. **Aristotle.**—As in other departments of knowledge, so in zoology the work of Aristotle is fundamental. It is wonderful to think of his knowledge of the forms and ways of life, or the insight with which he foresaw such useful distinctions as that between analogous and homologous organs, or his recognition of the fact of correlation, of the advantages of division of labour within organisms, of the gradual differentiation observed in development. He planted seeds which grew after long sleep into comparative anatomy and classification. Yet with what

sublime humility he says: "I found no basis prepared, no models to copy. Mine is the first step, and therefore a small one, though worked out with much thought and hard labour." Aristotle saw in Nature a process of progressive chance, the expression of an inherent perfecting principle.

"In nature, the passage from inanimate things to animals is so gradual that it is impossible to draw a hard-and-fast line between them. After inanimate things come plants, which differ from one another in the degree of life which they possess. Compared with inert bodies, plants seem endowed with life; compared with animals, they seem inanimate. From plants to animals the passage is by no means sudden or abrupt; one finds living things in the sea about which there is doubt whether they be animals or plants." "Animals are at war with one another when they live in the same place and use the same food. If the food be not sufficiently abundant they fight for it even with those of the same kind."

3. Lucretius.—Among the Romans Lucretius gave noble expression to the philosophy of Epicurus. We cannot here discuss his materialistic theory of the concourse of atoms into stable and well-adapted forms, but must be content with quoting a few sentences in which he states his belief that the earth is the mother of all life, and that animals work out their destiny in a struggle for existence. He was a cosmic, but hardly an organic evolutionist, for, according to his poetic fancy, organisms arose from the earth's fertile bosom and not by the gradual transformation of simpler predecessors.

"In the beginning the earth gave forth all kinds of herbage and verdant sheen about the hills and over all the plains; the flowery meadows glittered with the bright green hue, and next in order to the different trees was given a strong and emulous desire of growing up into the air with full unbridled powers. . . . With good reason the earth has gotten the name of mother, since all things have been produced out of the earth. . . .

"We see that many conditions must meet together in things in order that they may beget and continue their kinds; first a supply of food, then a way in which the birth-producing seeds throughout the frame may stream from the relaxed limbs. . . . And many races of living things must then have died out and been unable to beget and continue their breed. For in the case of all things which you see breathing the breath of life, either craft or courage or else speed

has from the beginning of its existence protected and preserved each particular race. And there are many things which, recommended to us by their useful services, continue to exist consigned to our protection.

"In the first place, the first breed of lions and the savage races their courage has protected, foxes their craft, and stags their proneness to flight. But light-sleeping dogs with faithful heart in breast, and every kind which is born of the seed of beasts of burden, and at the same time the woolly flocks and the horned herds, are all consigned to the protection of man. For they have ever fled with eagerness from wild beasts, and have ensued peace, and plenty of food obtained without their own labour, as we give it in requital of their useful services. But those to whom nature has granted none of these qualities, so that they could neither live by their own means nor perform for us any useful service, in return for which we should suffer their kind to feed and be safe under our protection, those, you are to know, would lie exposed as a prey and booty of others, hampered all in their own death-bringing shackles, until nature brought that kind to utter destruction."

4. **Evolutionists before Darwin.**—We must guard against supposing that the works of Buffon, or Lamarck, or Darwin were inexplicable creations of genius, or that they came like cataclysms, without warning, to shatter the conventional traditions of their time. For all great workers have their forerunners, who prepare their paths. The evolution of theories of evolution is bound up with the whole progress of the world. Therefore the student who would understand the development of the modern conception of organic evolution will have to take account of social changes, such as the collapse of the feudal system, the crusades, the invention of printing, the discovery of America, the French Revolution, the beginning of the steam age; of theological and religious movements, such as the Protestant Reformation and the spread of Deism; of a long series of evolutionist philosophers, some of whom were at the same time students of the physical sciences—notably Descartes, Spinoza, Leibnitz, Herder, Kant, and Schelling; of the acceptance of evolutionary conceptions in regard to other orders of facts, especially in regard to the earth and the solar system; and, finally, of those few naturalists, like De Maillet and Robinet, who, before Buffon's day, whispered evolutionist heresies. The history of an idea

is like that of an organism in which cross-fertilisation and composite inheritance complicate the pedigree.

5. **Three Old Masters.**—Among the evolutionists before Darwin three stand out prominently—Buffon, Erasmus Darwin, and Lamarck.

BUFFON (1707–1788) was born to wealth and was wedded to Fortune. He sat in kings' houses, his statue adorned their gardens. As Director of the *Jardin du Roi* he had opportunity to acquire a wide knowledge of animals. He commanded the assistance of able collaborateurs, and his own industry was untiring. He was about forty years old when he began his great Natural History, and he worked till he was fourscore. He lived a full life, the success of which we can almost read in the strong confidence of his style. "Le style, c'est l'homme même," he said; or again, "Le style est comme le bonheur; il vient de la douceur de l'âme." Rousseau called him "La plus belle plume du siècle"; Mirabeau said, "Le plus grand homme de son siècle et de bien d'autres." We have pleasant pictures of his handsome person, his magnificence, and his diplomatic manners. He had a splendid genius, which he mistakenly called "a supreme capacity for taking pains."

Buffon's culture was very wide. He had an early training in mathematics, and translated Newton's *Fluxions*; he seems to have been familiar with the chemistry and physics of his time; he was curious about everything. Before Laplace, he elaborated an hypothesis as to the origin of the solar system; before Hutton and Lyell, he realised that causes like those now at work had in the long past sculptured the earth; he had a special theory of heredity not unlike Darwin's, and a by no means narrow theory of evolution, in which he recognised the struggle for existence and the elimination of the unfit, the influence of isolation and of artificial selection, but especially the direct action of food, climate, and other surrounding influences upon the organism.

It is probable that Buffon's treatment of zoology gained freedom because he wrote in French, having shaken off the shackles which the prevalent custom of writing in

Latin imposed, and it cannot be doubted that his works did something to prepare the way for the future reception of the doctrine of descent. He had a vivid feeling of the unity of nature, throwing out hints in regard to the fundamental similarity of different forms of matter, suggesting that heat and light are atomic movements, denying the existence of hard-and-fast lines ("Le vivant et l'animé est une propriété physique de la matière!"), protesting against crude distinctions between plants and animals, and realising above all that there is one great family of life. Naturalists had been wandering up and down the valleys studying their characteristic contours; Buffon took an eagle's flight and saw the connected range of hills,—"l'enchainement des êtres."

Erasmus Darwin (1731–1802), grandfather to the author of the *Origin of Species*, was a large-hearted, thoughtful physician, whose life was as full of pleasant eccentricities, as his stammering speech of wit, and his books of wisdom. We have pleasant pictures of the philosophical physician of Lichfield and Derby, driving about in a whimsical unstable carriage of his own contrivance, prescribing abundant food and cowslip wine, rich in good health and generosity. Comparing his writings with those of Buffon, an acquaintance with which he evidently possessed, we find more emotion and intensity, more of the poet and none of the diplomatist. He approached the study of organic life on the one hand as a physician and physiologist, on the other hand as a gardener and lover of plants; and, apart from poetic conceits, his writings are characterised by a directness and simplicity of treatment which we often describe as "common-sense."

He believed that the different kinds of plants and animals were descended from a few ancestral forms, or possibly from one and the same kind of "vital filament," and that evolutionary change was mainly due to the exertions which organisms made to preserve or better themselves. He showed that animals were driven to exertion by hunger, by love, and by the need of protection, and explained their progress as the result of their

endeavours. Buffon laid especial emphasis upon the direct transforming influence of surroundings; Erasmus Darwin attached more importance to the moulding power of changed function. Let us quote some conclusions from his *Zoonomia* (1794):—

"Owing to the imperfection of language the offspring is termed a *new* animal, but is in truth a branch or elongation of the parent, since a part of the embryon animal is, or was, a part of the parent, and therefore in strict language cannot be said to be entirely *new* at the time of its production; and therefore it may retain some of the habits of the parent-system."

"The fetus or embryon is formed by apposition of new parts, and not by the distention of a primordial nest of germs included one within another like the cups of a conjuror."

"From their first rudiment, or primordium, to the termination of their lives, all animals undergo perpetual transformations; which are in part produced by their own exertions in consequence of their desires and aversions, of their pleasures and their pains, or of irritations, or of associations; and many of these acquired forms or propensities are transmitted to their posterity."

"As air and water are supplied to animals in sufficient profusion, the three great objects of desire, which have changed the forms of many animals by their exertions to gratify them, are those of lust, hunger, and security."

"This idea of the gradual generation of all things seems to have been as familiar to the ancient philosophers as to the modern ones, and to have given rise to the beautiful hieroglyphic figure of the πρῶτον ᾠόν, or first egg, produced by night, that is, whose origin is involved in obscurity, and animated by ἐρώς, that is, by Divine Love; from whence proceeded all things which exist."

On LAMARCK (1744–1829) success did not shine as it did on the Comte de Buffon or on Dr. Erasmus Darwin. His life was often so hard that we wonder he did not say more about the struggle for existence. As a youth of sixteen, destined for the Church, he rides off on a bad horse to join the French army, then fighting in Germany, and bravely wins promotion on his first battle-field. After the peace he is sent into garrison at Toulon and Monaco, where his scientific enthusiasm is awakened by the Flora of the south. Retiring in weakened health from military service, he earns his living in a Parisian banker's office, devotes his spare energies to the study of plants, and writes a *Flore française* in three volumes, the publi-

cation of which (1778) at the royal press was secured by Buffon's patronage. As tutor to Buffon's son, he travels in Europe and visits some of the famous gardens, and we can hardly doubt that Buffon influenced Lamarck in many ways. After much toil as a literary hack and scientific drudge, he is elected to what we should now call a Professorship of Invertebrate Zoology, a department at that time chaotic. In 1794 he began his lectures, and each year brought increased order to his classification and museum alike. At the same time, however, he was lifting his anchors from the orthodox moorings, relinquishing his belief in the constancy of species, following (we know not with what consciousness) the current which had already borne Buffon and Erasmus Darwin to evolutionary prospects. In 1802 he published *Researches on the Organisation of Living Bodies*; in 1809 a *Philosophie Zoologique*; from 1816–1822 his *Natural History of Invertebrate Animals*, a large work in seven volumes, part of which the blind naturalist dictated to his daughter. Busy as he must have been with zoology, his restless intellect found time to speculate—it must be confessed to little purpose—on chemical, physical, and meteorological subjects. Thus he ran an unsuccessful tilt against Lavoisier's chemistry, and published for ten years annual forecasts of the weather, which seem to have been almost always wrong. Nor did Lamarck add to his reputation by a theory of *Hydrogeology*, and his scientific friends who were loyal specialists shrugged their shoulders more and more over his intellectual knight-errantry.

Poverty also clouded his later years, his treasured collections had to be sold for bread, his theories made no headway, his merits were unrecognised. Yet now a Lamarckian school is strong in France and in America, and even those who deny his doctrines admit that he was one of the bravest of pioneers.

Of Lamarck's *Philosophie Zoologique*, Haeckel says: "This admirable work is the first connected and thoroughly logical exposition of the theory of descent." And again, he says: "To Lamarck will remain the immortal glory of having for the first time established the

theory of descent as an independent scientific generalisation of the first order, as the foundation of the whole of Biology." But the fact is that Lamarck is much more appreciated now than he was by his contemporaries. Thus Cuvier, in his *Éloge de M. de Lamarck* delivered before the French Academy in 1832, said, "A system resting on such foundations may amuse the imagination of a poet, etc., . . . but it cannot for a moment bear the examination of any one who has dissected the hand, the viscera, or even a feather." Cuvier was an investigator of the highest rank, yet was not free from obscurantism.

Let us hear Lamarck himself :—

"Nature in all her work proceeds gradually, and could not produce all the animals at once. At first she formed only the simplest, and passed from these on to the most complex."

"The limits of so-called species are not so constant and unvarying as is commonly supposed. Spontaneous generation started each particular series, but thereafter one form gives rise to another. In life we should see, as it were, a ramified continuity if certain species had not been lost."

"The operations of Nature in the production of animals show that there is a primary and predominant cause which gives to animal life the power of progressive organisation, of gradually complicating and perfecting not only the organism as a whole, but each system of organs in particular."

"*First Law.* Life by its inherent power tends continually to increase the volume of every living body, and to extend the dimensions of its parts up to a self-regulated limit.

"*Second Law.* The production of a new organ in an animal body results from the occurrence of some new need which continues to make itself felt, and from a new movement which this need originates and sustains.

"*Third Law.* The development of organs and their power of action are constantly determined by the use of these organs.

"*Fourth Law.* All that has been acquired, begun, or changed in the structure of individuals during the course of their life is preserved in reproduction and transmitted to the new individuals which spring from those which have experienced the changes."

These four laws are from Lamarck's *Histoire Naturelle.* The following passages, translated by Samuel Butler from the *Philosophie Zoologique*, give a further statement of

the characteristic Lamarckian theory of the transforming power of use and disuse :—

"Every considerable and sustained change in the surroundings of any animal involves a real change in its needs."

"Such change of needs involves the necessity of changed action in order to satisfy these needs, and, in consequence, of new habits."

"It follows that such and such parts, formerly less used, are now more frequently employed, and in consequence become more highly developed ; new parts also become insensibly evolved in the creature by its own efforts from within."

"These gains or losses of organic development, due to use or disuse, are transmitted to offspring, provided they have been common to both sexes, or to the animals from which the offspring have descended."

The historian of evolution theories has, of course, to take account of many workers besides Buffon, Erasmus Darwin, and Lamarck ; of Treviranus (1776–1837), whose *Biology or Philosophy of Living Nature* (1802–1805) is full of evolutionary suggestions ; of Geoffroy St. Hilaire, who in 1830, before the French Academy of Science, fought with Cuvier, the fellow-worker of his youth, an intellectual duel on the question of descent ; of Goethe, who, in his eighty-first year, heard the tidings of Geoffroy's defeat with an interest which transcended the political anxieties of the time, and whose own epic of evolution surpasses that of Lucretius ; of Oken's speculative mist, amid which the light of evolutionary ideas danced like a will-o'-the-wisp ; of many others in whose mind the truth grew if it did not blossom. But we must now pass to the work of Charles Darwin.

6. **Darwin.**—Marcus Aurelius gave thanks in his roll of blessings that he had not been suffered to keep quails ; so Darwin, in recounting his mercies, did not forget to be grateful for having been preserved from the snare of becoming a specialist. From a more partial point of view, we have reason to be thankful that he became a specialist, not in one department, but in many. As a disciple of Linnæus, he described the species of barnacles in one volume, and followed in the steps of Cuvier in anatomising them in another. Of tissues and cells he knew less, being as regards these items an antediluvian,

and outside the guild of those who dexterously wield the razor, and in so doing observe the horoscope of the organism. Of protoplasm, in regard to which modern biology says so much and knows so little, he was not ignorant, for did he not study the marvels of the state known as "aggregation"?

But it is not for special research that men are most grateful to Darwin. Undoubtedly, if clear insight into the world around us be esteemed in itself of value, the author of *Insectivorous Plants*, *The Fertilisation of Orchids*, *The Movements of Plants*, *The Origin of Coral Reefs*, *The Formation of Vegetable Mould*, etc., runs no risk of being forgotten. But though our possession of these results swells the meed of praise, we usually regard them as outside of Darwin's real work, which, as every one knows, was his contribution to the theory of organic life.

This contribution was threefold—(*a*) He placed the theory of descent on a sure basis; (*b*) he shed the light of this doctrine on various groups of phenomena; and (*c*) he tackled the problem of the factors in evolution.

(*a*) The man who makes us believe a fact is to us more important than the original discoverer. And so Darwin gets credit for inventing the theory of descent, which in principle is as old as clear thought itself, and in its biological application was stated a hundred years before the publication of the *Origin of Species* (1859). The conception was no new one, but Darwin first made men believe it. The idea was not his, but he gave it to many. He did not originate; he established. He converted naturalists to an evolutionary conception of the organic world.

(*b*) Having got people to believe the theory of descent,—the theory of development out of preceding conditions,—Darwin went on to show how the conception would illumine all facts to which it was applicable. In his work on the expression of emotions, and in scattered chapters, he showed how the light might be shed upon the secrets of mental activity. Whenever it was seen that the doctrine could justify itself in regard to general organic life, it was eagerly seized as an organon for the explora-

tion of special sets of facts. The phœnix revived and flew croaking amid the smoke of burning systems. How one discussed the evolution of language, and another that of industry; how the natural history of ethics was sketched by one thinker, and the growth of institutions by another; how the conception has forced its way into the cloister and the political arena, and has even found expression in theories of literature, art, and religion,—is an often-repeated story.

(*c*) We have noticed that Buffon, and, let us add, Treviranus, firmly maintained that the direct influence of the external conditions of life was an important factor in evolution. We have also seen that Erasmus Darwin and Lamarck were strongly convinced of the transforming power of use and disuse. When Charles Darwin began to think and write on the origin of species, he also recognised the transforming influences of function and of environment. But with the Buffonian or Lamarckian position he was never satisfied; he advanced to one of his own—to the theory of natural selection, the characteristic feature of Darwinism.

Let us state this theory, which was foreseen by Matthew, Wells, Naudin, and others, was developed simultaneously by Darwin and by Alfred Russel Wallace, and has attained remarkable acceptance throughout the world.

All plants and animals produce offspring which, though like their parents, usually differ from them in possessing some new features or variations. How these arise is obscure; they are the outcome of changes in the germinal material. But throughout nature there is a struggle for existence in which only a small percentage of the organisms born survive to maturity or reproduction. Those which survive *may* do so because of the individual peculiarities which have made them in some way more fit to survive than their fellows. Moreover the favourable variation possessed by the survivors is handed on as an inheritance to their offspring, and tends to be corroborated when the new generation is bred from parents both possessing the happily advantageous character. This natural fostering

of advantageous variations and natural elimination of those less fit, explain the general transformation and adaptation of species, as well as the general progress from simpler to higher forms of life.

This theory that favourable variations may be fostered and accumulated by natural selection till useful adaptations result is the chief characteristic of Darwinism. Of this theory Prof. Ray Lankester says:

> "Darwin by his discovery of the mechanical principle of organic evolution, namely, the survival of the fittest in the struggle for existence, completed the doctrine of evolution, and gave it that unity and authority which was necessary in order that it should reform the whole range of philosophy."

And again he says:

> "The history of zoology as a science is therefore the history of the great biological doctrine of the evolution of living things by the natural selection of varieties in the struggle for existence,—since that doctrine is the one medium whereby all the phenomena of life, whether of form or function, are rendered capable of explanation by the laws of physics and chemistry, and so made the subject-matter of a true science or study of causes."

We have quoted these sentences because they illustrate the exaggeration to which enthusiasm for a great theory may lead a strong intellect. Beside them we would place a few sentences from Samuel Butler, which will serve to show that the most brilliant critics of Darwinism may also be extreme. Perhaps the contrast between our two quotations may stimulate the reader to inquire into the matter for himself.

> "Buffon planted, Erasmus Darwin and Lamarck watered, but it was Mr. Darwin who said 'That fruit is ripe,' and shook it into his lap. . . . Darwin was heir to a discredited truth, and left behind him an accredited fallacy. . . . Do animals and plants grow into conformity with their surroundings because they and their fathers and mothers take pains, or because their uncles and aunts go away? . . . The theory that luck is the main means of organic modification is the most absolute denial of God which it is possible for the human mind to conceive. . . ."

7. Darwin's Fellow-workers.—But we must bring this historical sketch to a close by referring to four of the

more prominent of Darwin's fellow-workers—Wallace, Spencer, Haeckel, and Huxley.

Alfred Russel Wallace (1822–1913) was contemporary with Darwin, not only in years, but in emphasising the truth of evolutionary conceptions, and in recognising the fact of natural selection. Of his magnanimity in collaboration, the late Mr. Romanes has said :

> "It was in the highest degree dramatic that the great idea of natural selection should have occurred independently and in precisely the same form to two working naturalists; that these naturalists should have been countrymen; that they should have agreed to publish their theory on the same day; and last, but not least, that, through the many years of strife and turmoil which followed, these two English naturalists consistently maintained towards each other such feelings of magnanimous recognition that it is hard to say whether we should most admire the intellectual or the moral qualities which, in relation to their common labours, they have displayed."

Mr. Wallace was a naturalist in the old and truest sense, rich in a world-wide experience of animal life, at once specialist and generaliser, a fearless thinker and a social striver, and a man of science who realised the spiritual aspect of the world.

He believed in the "overwhelming importance of natural selection over all other agencies in the production of new species," differed from Darwin in regard to sexual selection, to which he attached little importance, and agreed with Weismann in regard to the non-transmission of individually acquired characters.

But the exceptional feature in Wallace's scientific philosophy was his contention that the higher characteristics of man are due to a special evolution hardly distinguishable from creation.

Herbert Spencer (1820–1903) published as early as 1852 a plea for the theory of organic evolution which is very remarkable in its strength and clearness. The work of Darwin supplied corroboration and fresh material, and in the *Principles of Biology* (1863–66) the theory of organic evolution first found philosophic, as distinguished from merely scientific expression. To Spencer we

owe the familiar phrase "the survival of the fittest," and that at first sight puzzling generalisation, "Evolution is an integration of matter and concomitant dissipation of motion, during which the matter passes from an indefinite incoherent homogeneity to a definite coherent heterogeneity, and during which the retained motion (energy) undergoes a parallel transformation." He devoted his life to establishing this generalisation, and applying it to physical, biological, psychological, and social facts. As to the factors in organic evolution, he emphasised the change-producing influences of environment and function, upheld the Lamarckian doctrine of the transmissibility of individually acquired somatic modifications, and recognised that natural selection works towards securing indirect equilibration by the elimination of the relatively less fit variants. He did not share the ultra-Darwinian confidence in "the all-sufficiency of Natural Selection," and the thoroughness of his Lamarckian convictions may be gauged by his remark: "Either there has been inheritance of acquired characters or there has been no evolution."

Ernst Haeckel, Professor of Zoology in Jena, and author of a great series of monographs on Radiolarians, Sponges, Jellyfish, etc., may be well called the Darwin of Germany. He has devoted his life to applying the doctrine of descent, and to making it current coin among the people. Owing much of his motive to Darwin, he stood for a time almost alone in Germany as the champion of a heresy. Before the publication of Darwin's *Descent of Man*, Haeckel was the only naturalist who had recognised the import of sexual selection; and of his *Natural History of Creation* Darwin writes: "If this work had appeared before my essay had been written, I should probably never have completed it." His most important expository works are the above-mentioned *Natürliche Schöpfungsgeschichte* (1868), which has passed through many editions, and his *Anthropogenie* (1874, translated as *The Evolution of Man*). These books are very brilliantly written, though they offend many by their aggressive impatience with theological dogma and

teleological interpretation. His greatest work, however, is of a less popular character, namely, the *Generelle Morphologie* (2 vols., Berlin, 1866), which in its reasoned orderliness and clear generalisations ranks beside Spencer's *Principles of Biology*.

THOMAS HENRY HUXLEY (1825–1895) was one of the first to stand by Darwin, and to wield a sharp intellectual sword in defence and attack. No one fought for the doctrine of descent in itself and in its consequences with more keenness and success than the author of *Man's Place in Nature* (1863), *American Addresses*, *Lay Sermons*, etc., and no one championed the theory of natural selection with more confident consistency or with more skilfully handled weapons.

8. **Steps of Progress since Darwin's Day.**—As Alfred Russel Wallace said in the preface to his *Darwinism* (1889): "Descent with modification is now universally accepted as the order of nature in the organic world." But while this remains true, there is anything but unanimity in regard to the way in which the ascent of life has come about, as to the working of the nature-loom. Naturalists are not within sight of any complete theory of the factors in organic evolution.

In regard to variations, the raw materials of evolution, some notable steps of progress have been made since Darwin's day. (1) Patient accumulation of facts has shown that variations are even more abundant than Darwin supposed. The fountain of change is inexhaustible. (2) The registration or plotting out of observed quantitative variations has shown that they usually form what is called the Curve of the Frequency of Error. There is a proportion between the frequency of a particular change, *e.g.* gigantic or dwarfish stature, and the amount of its departure from the mean of the character in question. (3) More evidence has been forthcoming of what Darwin called the "correlation of variations." That is to say, a number of changes in an organism are often linked together, being different expression of some single deeper change. (4) Discontinuous or brusque variations are much more frequent than Darwin

supposed. The work of Bateson and of De Vries has shown that changes of considerable magnitude may occur at a single leap. When the new character that appears suddenly has a considerable degree of perfection from the moment of its emergence, is independently heritable, and does not blend, it is called a mutation. (5) These mutations are not liable to be swamped by intercrossing, as Darwin supposed. They have great staying power in inheritance, reappearing persistently in a certain proportion of the descendants. (6) Structural changes directly induced in the life-time of the individual by some peculiarity in environment or in function are distinguished as somatic modifications, or, unfortunately, as "acquired characters." Variations are endogenous or blastogenic, arising from a change in the germ-plasm; modifications are exogenous or somatogenic, impressed from without. There is no convincing evidence that modifications are as such or in any representative degree transmissible. (7) As to the origin of variations, we must still confess with Darwin that "our ignorance of the laws of variation is profound," but certain possibilities have become clearer. Thus certain kinds of variation are interpretable as due to a dropping out of some constituent or factor in the inheritance, others as due to an augmentation of a factor; others as due to a novel arrangement or pattern of factors which were present in the ancestry; and there are in the history of the germ-cells various opportunities (*e.g.* in maturation and fertilisation) for such new permutations and combinations. Then again it is possible that environmental stimuli operating from the outer world, or fluctuations in the nutritive stream within the body may induce changes in the complex germ-plasm. But as to new departures of moment, it is not possible at present to offer any explanation. They are expressions of a primary quality of living organisms—for the germ-cell is an implicit organism. They are manifestation of a capacity for creative evolution. They seem to us like experiments in self-expression.

In regard to heredity, the scientific study of which may be said to have been inaugurated by Darwin, some notable

advances have been made. (1) It has become clear that heredity is not a force or power, but the relation of genetic continuity between successive generations; that inheritance includes all that the organism is, or has, to start with in virtue of its hereditary relation; and that development is the expression of the hereditary "nature" under the influence of appropriate "nurture." The idea of the continuity of the germ-plasm, which has been already explained, has clarified the general concepts of heredity and inheritance. (2) There has been an increasing precision in the demonstration of the heritability of particular characters, including subtle qualities like longevity and fecundity and immunity. Excepting sterility, any kind of character that appears as an inborn feature in an organism *may be* transmitted to the next generation. (3) It has been shown that there are numerous hereditary characters which behave in a distinctive and independent way in inheritance: they do not blend or intergrade, they are infallibly present in a certain proportion of the offspring, they are either there or not there. Such characters are called "unit-characters," and sometimes, at least, they arise as mutations. In his book on *Mendelism*, Prof. R. C. Punnett refers to a unit-character as follows:

> "Unit-characters are represented by definite factors in the gamete which, in the process of heredity, behave as indivisible entities, and are distributed according to a definite scheme. The factor for this or that unit-character is either present in the gamete (*i.e.* the germ-cell), or it is not present. It must be there in its entirety, or be completely absent."

(4) Besides the Mendelian mode of inheritance, there appear to be others, especially what is called blending, where the offspring is, as regards certain characteristics, like a thoroughgoing mixture of the corresponding paternal and maternal qualities. But *many* instances of what used to be called blending and of what used to be called reversion, and regarded as distinct modes of inheritance, turn out to be interpretable as Mendelian. (5) The result of much discussion and a few striking experiments bearing on the transmissibility

of somatic modifications or individually acquired characters directly due to peculiarities of nurture, has been to strengthen the negative position, that the assumption of the transmissibility of these changes in any direct and specific way is not at present warranted by the facts.

As regards the process of selection, (1) one of the distinct steps of progress since Darwin's day has been the demonstration of a few clear cases of natural selection at work. That is to say, it has proved in a few cases that the elimination is discriminate, that the survivors survive in virtue of the presence of particular qualities. Thus Cesnola tethered green Mantises on green herbage and brown Mantises on brown herbage and found that they escaped the eyes of birds. But green Mantises on brown herbage and brown Mantises on green herbage were rapidly picked off. (2) Another step has been a recognition of the manifoldness of selective processes. Thus there is "lethal" selection, which works by the discriminate elimination of the relatively less fit to the given conditions, and "reproductive" selection, which works through the increased and more effective reproductivity incident on the success of the relatively more fit. And again, there may be selection among the germ-cells themselves, where extraordinary thinning of numbers is prevalent; and possibly an intra-germinal selection among constituent items or determinants in the inheritance. There may be selection of males by the females, or of females by the males, or of the males by one another, but little progress has been made since Darwin's day in the study of preferential mating. (3) In the early days of Darwinism there was sometimes a tendency, which Darwin's works do not countenance, to think and speak too simply of the processes of selection. It is clear that the process need not in the least imply a sudden elimination of the relatively less fit, for a shortened life and a less successful family will work equally well in the long run. It must be realised that the complexity of the web of life is such that even slight peculiarities may be of critical moment in determining the survival of the variants possessing them. And just as in sexual selec-

tion what determines the female's preference for one suitor out of many is more probably an irresistible tout-ensemble of gifts and graces and not excellence in one particular decoration or quality, so in natural selection it may be that what gives survival value is often a general stability of constitution and efficiency of behaviour. (4) In so far as selection is in terms of a previously established systematisation of inter-relations—the web of life—there will be a reduction of fortuitousness and capriciousness. Natural selection is largely automatic in its working, but in so far as the eliminating sieve is an external system of adaptations, the sifting will differ from "a chapter of accidents." Moreover, the sifting process rises beyond the automatic whenever the living creature takes a share in its own evolution, as it often does, by selecting, changing, or even making its own environment, or by active endeavours after well-being, experiments with Fate, and traffickings with Time.

"I do not doubt," said Darwin, "that isolation is of considerable importance in the formation of new species," and many evolutionists—Wagner, Weismann, Gulick, Romanes, Jordan, and others—have worked at the idea of Isolation as a directive factor in evolution. The term is applied to all the means which restrict the range of intercrossing within a species, whether the barriers are spatial, or temporal, or habitudinal, or physiological, or psychical. It is probable that isolation favours the origin of distinct species by preventing intercrossing and still more by bringing about close in-breeding.

	(ENVIRONMENT)	(ORGANISM)	(FUNCTION)
Primary or Originative Factors	Changes or peculiarities in the environment are sometimes followed by changes in the organism (especially during plastic stages) either (*a*) in the body only, or (*b*) in the germ-cells only, or (*c*) in both.	Germinal variations may arise from the nature of protoplasm, or from changes in the nutritive environment of the germ-cells, or from deeply saturating environmental stimuli, or from the opportunities for rearrangements offered in maturation and fertilisation and otherwise, or from the nature of the germ-cell as an implicit organism which may, like an explicit organism, experiment in self-expression.	Altered use and disuse of parts, or peculiarities in function (often evoked by changed environment) are sometimes followed by changes in the organism (especially during plastic stages),—either (*a*) in the body only, or (*b*) in the germ-cells only, or (*c*) in both.
	Result on the body of the individual—Environmental somatic modifications.	*Result—Variations continuous and discontinuations, fluctuations and mutations.*	*Result on the body of the individual—Functional somatic modifications.*
Secondary or Directive Factors	Degree of transmissibility (if any) of environmental somatic modifications unknown.	Transmissible.	Degree of transmissibility (if any) of functional somatic modifications unknown.
	Such environmental *modifications*, IF transmitted, and if the originating conditions persist for some generations, might perhaps give rise to new species, if favoured by natural selection and isolation. If not transmitted, they may nevertheless serve a purpose in the individual life, *e.g.* in shielding the incipient stages of *variations* in the same or a similar direction.	Such innate *variations* probably supply the usual material for the origin of new species, for the establishment of which, more or less natural selection (elimination) and isolation may be necessary, according to the nature of the variation, whether a slight advance or a transilient leap.	Such functional *modifications* IF transmitted, and if the originating conditions persist for some generations, might perhaps give rise to new species, if favoured by natural selection and isolation. If not transmitted, they may nevertheless serve a purpose in the individual life, *e.g.* in shielding the incipient stages of *variations* in the same or in a similar direction.

APPENDIX

SOME USEFUL BOOKS DEALING WITH ANIMAL LIFE

* Those marked with an asterisk may be particularly recommended to begin with. But the best beginning is always where the personal tendril fixes.

INTRODUCTORY BOOKS

F. JEFFREY BELL, " Comparative Anatomy and Physiology " (1895).
ARABELLA B. BUCKLEY, " Life and her Children."
——— " Winners in Life's Race."
*G. N. CALKINS, " Biology " (New York, 1914).
W. H. FLOWER, " The Horse " (1891).
*F. W. GAMBLE, " Animal Life " (1908).
——— " The Animal World " (Home University Library).
*C. F. HODGE, " Nature Study and Life " (Boston, 1902).
T. H. HUXLEY, " The Crayfish, an Introduction to the Study of Zoology " (Internat. Sci. Series, 1880).
J. GRAHAM KERR, " Zoology " (Dent's Scientific Primers).
O. LATTER, " Natural History of Common Animals " (Cambridge, 1904).
B. LINDSAY, " An Introduction to the Study of Zoology " (1895).
*R. LULHAM, " Introduction to Zoology " (1913).
A. MILNE MARSHALL, " The Frog " (11th ed. by F. W. Gamble, 1914).
P. CHALMERS MITCHELL and G. P. MUDGE, " Outlines of Biology " (3rd ed. 1911).
C. LLOYD MORGAN, " Animal Biology."
J. G. NEEDHAM, " General Biology " (Ithaca, 1910). A very fresh and educative introduction.
*M. I. NEWBIGIN, " Life by the Seashore " (1901).
ST. GEORGE MIVART, " The Frog " (Nature Series, London, 1874).
T. JEFFERY PARKER, " Elementary Biology " (1891).
T. JEFFERY PARKER and W. A. HASWELL, " A Manual of Zoology."
*" Some Secrets of Nature: Short Studies in Field and Wood." With an introduction by W. J. P. Burton (1913). A very good, simple book on Socratic lines.

TEXTBOOKS OF ZOOLOGY

G. C. Bourne, "An Introduction to the Study of the Comparative Anatomy of Animals" (2 vols.).

Hatchett Jackson, Edition of Rolleston's "Forms of Animal Life" (Oxford, 1888).

E. Ray Lankester and others, "Treatise on Zoology" (many volumes).

T. Jeffery Parker and W. A. Haswell, "A Text-book of Zoology" (2 vols. 1897).

A. Sedgwick, "Student's Text-Book of Zoology," Part I. (London, 1898), Part II. (1905), Part III. (1909).

A. E. Shipley and E. W. MacBride, "Zoology, an Elementary Text-Book" (2nd ed. 1904).

J. Arthur Thomson, "Outlines of Zoology" (6th ed. London, 1914).

GUIDES TO PRACTICAL WORK

J. E. Barnard, "Practical Photo-micrography" (1911).

British Museum "Guides to Collectors."

W. K. Brooks, "Handbook of Invertebrate Zoology for Laboratories and Seaside Work" (Boston, 1882).

Challenger Society, "The Science of the Sea" (1912). Edited by G. Herbert Fowler.

Dallinger, "The Microscope" (1891).

W. Furneaux, "The Outdoor World, or Young Collector's Handbook" (1905).

S. H. Gage, "The Microscope: an Introduction to Microscopic Methods and to Histology" (New York, 1904).

P. H. Gosse, "The Aquarium" (1854).

M. F. Guyer, "Animal Micrology" (Chicago, 1909).

G. B. Howes, "Atlas of Practical Elementary Biology" (London, 1885).

A. Bolles-Lee, "Microtomist's Vade-mecum" (7th ed. 1913).

P. Kammerer, "Das Terrarium und Insektarium" (Leipzig).

Marshall and Hurst and Gamble, "Practical Zoology" (7th ed. 1912).

Monographs on Marine Types (Sea-urchin, Lobworm, Limpet, Ascidian, etc.), published by Liverpool Biological Committee (Williams & Norgate).

Nägeli and Schwendener, "The Microscope in Theory and Practice" (trans. 1887).

T. J. Parker, "Zootomy" (London, 1884).

T. J. Parker and W. N. Parker, "Practical Zoology" (2nd ed. 1908).

J. Rennie, "School Lessons in Plant and Animal Life" (1912).

F. Shillington Scales, "Practical Microscopy, an Introduction to Microscopical Methods" (1909).

E. J. Spitta, "Microscopy: the Construction, Theory, and Use of the Microscope" (1909).

J. E. Taylor, "The Aquarium" (1881).

Burt G. Wilder and S. H. Gage, "Animal Technology" (3rd ed. 1892).

Sir Almroth E. Wright, "Principles of Microscopy, being a Handbook to the Microscope" (1906).

GENERAL NATURAL HISTORY (ŒCOLOGY, Etc.)

C. C. Adams, "Guide to the Study of Animal Ecology" (New York, 1913). A valuable introduction to literature and methods.

*Charles Darwin, "The Formation of Vegetable Mould through the Action of Worms" (1881).

K. Groos, "The Play of Animals" (trans. 1900).

Hesse and Doflein, "Tierbau und Tierleben" (2 vols. Leipzig and Berlin, 1910 and 1914). Doflein's volume on "Tierleben" is a treasury of modern natural history.

Hilzheimer and Haempel, "Handbuch der Biologie der Wirbeltiere" (2 vols. Stuttgart, 1912 and 1913).

D. S. Jordan and V. L. Kellogg, "Evolution and Animal Life" (New York, 1907).

W. Kirby and W. Spence, "Introduction to Entomology" (London, 1815).

*Sir Ray Lankester, "Science from an Easy Chair" (1910).

*——— "From an Easy Chair" (1908).

George Henry Lewes, "Studies in Animal Life" (1862).

Sir John Lubbock (Lord Avebury), "Ants, Bees, and Wasps" (Internat. Sci. Series).

R. Lydekker, J. T. Cunningham, G. A. Boulenger, and J. Arthur Thomson, "Reptiles, Amphibia, Fishes, and Lower Chordates" (London, 1912). Continuing Pycraft's "Birds."

Nusbaum, Karsten, and Weber, "Lehrbuch der Biologie" (Leipzig, 1911).

*W. P. Pycraft, "History of Birds" (1910). Rich in œcological material and suggestion.

K. Semper, "The Natural Conditions of Existence as they affect Animal Life" (Contemp. Sci. Series, 1881).

Shelford, "Animal Communities" (Chicago, 1914).

*J. Arthur Thomson, "Biology of the Seasons" (1911).

*——— "The Wonder of Animal Life" (1914).

*Margaret Thomson and J. Arthur Thomson, "Threads in the Web of Life" (1910). For young people.

Alfred Russel Wallace, "Island Life" (1880).

W. M. Wheeler, "Ants" (Columbia University Series).

*Gilbert White, "Natural History of Selborne" (1788).

J. G. Wood, "Homes without Hands" (1873), and other works.

PARTICULAR ŒCOLOGICAL STUDIES

INTER-RELATIONS OF FLOWERS AND INSECTS:

CHARLES DARWIN, "Fertilisation of Orchids" (1862).
——— "Cross-Fertilisation" (1876).
——— "Insectivorous Plants."
HERMANN MÜLLER, "Fertilisation of Flowers by Insects" (trans. by D'Arcy Thompson, London, 1883).
*PATRICK GEDDES, "Chapters in Modern Botany" (1893).
KERNER, "Flowers and their Unbidden Guests."
——— "Natural History of Plants" (Vol. I.).
LUBBOCK, "British Wild Flowers in Relation to Insects" (1875).

OTHER INTER-RELATIONS:

L. CUÉNOT, "Les Moyens de défense dans la série animale" (Paris).
CHARLES DARWIN, "The Formation of Vegetable Mould through the Agency of Worms" (1881).
*S. GAYE, "The Great World's Farm" (London, 1893).
WIESNER, "Biologie der Pflanzen" (Wien, 1889).
E. A. ORMEROD, "Injurious Insects" (2nd ed. London, 1891).
GOEBEL, "Pflanzenbiologische Schilderungen" (Marburg, 1889).
SCHIMPER, "Wechselbeziehungen zwischen Pflanzen und Ameisen" (Jena, 1883).
O. HERTWIG, "Die Symbiose" (Jena, 1883).
*VAN BENEDEN, "Animal Parasites and Messmates" (Internat. Sci. Series, London, 1876).
E. T. CONNOLD, "British Oak Galls" (1908).
*F. KEEBLE, "Plant-Animals" (Cambridge, 1910).
F. DOFLEIN, "Das Tier als Glied des Naturganzen," Vol. II. of "Tierbau und Tierleben" (Hesse & Doflein, Leipzig and Berlin, 1914).
H. KRAEPELIN, "Die Beziehungen der Tiere zueinander und zur Pflanzenwelt" (Leipzig, 1905).
L. LALOY, "Parasitisme et mutualisme dans la nature" (Bibliothèque Scient. Internat., Paris, 1906).
J. H. FABRE, "Social Life in the Insect World" (trans. 1912).

RECREATIVE NATURE-STUDIES

GRANT ALLEN, "Vignettes from Nature," "The Evolutionist at Large."
FRANK BUCKLAND, "Curiosities of Natural History" (London, 1872–1877).
JOHN BURROUGHS, "Wake Robin" (1871).
——— "Winter Sunshine" (1875).
——— "Birds and Poets" (1877).
——— "Locusts and Wild Honey" (1879).
——— "Fresh Fields" (1884); "The Breath of Life" (1915), etc.

J. Colquhoun, "The Moor and the Loch" (Edinburgh, 1840; 8th ed. 1878).
J. H. Fabre, "Souvenirs entomologiques" (Paris).
P. H. Gosse, "Romance of Natural History" (2 vols. London, 1860–1861).
P. G. Hamerton, "Chapters on Animals."
Richard Jefferies, "The Gamekeeper at Home" (1878).
——— "Wild Life in a Southern County" (1879).
——— "Nature near London" (1883).
——— "Life of the Fields" (1884).
——— "The Open Air" (1885); etc.
Charles Kingsley, "Glaucus" (1854).
——— "Water-Babies."
F. A. Knight, "Idylls of the Field" (London, 1889).
——— "By Leafy Ways."
W. McConnachie, "Close to Nature's Heart" (1908).
——— "In the Lap of the Lammermoors" (1913).
L. C. Miall, "House, Garden, and Field" (1905).
C. Lloyd Morgan, "Sketches of Animal Life" (London, 1892).
Phil Robinson, "The Poet's Birds" (London, 1883).
——— "The Poet's Beasts" (London, 1885).
John Ruskin, "Love's Meinie" (1881).
——— "Eagle's Nest."
——— "Queen of the Air"; etc.
Charles St. John, "Wild Sports and Natural History of the Highlands" (London, illus. ed. 1878).
Henry Thoreau, "Walden."
——— "A Week on Concord."
Andrew Wilson, "Leaves from a Naturalist's Notebook."
——— "Chapters on Evolution."

SEASONAL NATURE-STUDIES

*Grant Allen, "Colin Clout's Calendar, the Record of a Summer" (1883).
C. W. Beebe, "Log of the Sun" (New York, 1906).
John Burroughs, "Signs and Seasons" (1886).
Cassell's "Nature-Book" (1908).
P. G. Hamerton, "The Sylvan Year" (1876; 3rd ed. 1883).
*L. C. Miall, "Round the Year" (1896).
J. A. Owen, "The Country Month by Month."
——— "Woodland, Moor, and Stream."
*J. Rennie, "The Aims and Methods of Nature Study. A Guide for Teachers" (1910).
K. Russ, "Das heimische Naturleben im Kreislauf des Jahres" (Berlin, 1889).
Edward Thomas and others, "British Country Life in Spring and Summer" (1907).
——— ——— "British Country Life in Autumn and Winter" (1907).

*J. Arthur Thomson, "The Natural History of the Year" (1896). For Young People. See also "Biology of the Seasons" (1911).
——— Appendix to Memorandum on Nature Study (Scotch Education Department, 1908).
*Gilbert White, "The Natural History and Antiquities of Selborne" (1788; Hastings's ed. 1888).
C. A. Witchell, "Nature's Story of the Year" (1904). See also "The Evolution of Bird Song" and "Cries and Calls of Wild Birds."
J. G. and Th. Wood, "The Field Naturalist's Handbook" (London, 1879). See also "Common Objects of the Country" (1858), "The Brook and its Banks" (1889).

ELEMENTARY PHYSIOLOGY

*W. T. Councilman, "Disease and its Causes" (Home University Library, American edition, 1913). Vivid physiological introduction.
W. B. Drummond, "Elementary Physiology, for Teachers and Others" (1909).
*T. H. Huxley, "Lessons in Elementary physiology" (revised ed. by Barcroft, 1915). Also his "Crayfish" (Internat. Sci. Series).
*J. G. McKendrick, "Physiology" (Home University Library, 1912).
——— "Life in Motion; or Muscle and Nerve" (1892).

GENERAL PHYSIOLOGY

W. M. Bayliss, "Principles of General Physiology" (1915).
A. Biedl, "The Internal Secretory Organs" (trans. 1912).
C. M. Child, "Individuality in Organisms" (Chicago, 1915).
*F. Czapek, "Chemical Phenomena in Life" (Harper's Library of Living Thought, 1911).
A. Dastre, "Life and Death" (trans. 1911).
Y. Delage, "L'Hérédité et les grands problèmes de la biologie générale" (Paris, 1895; 2nd ed. 1902).
J. S. Haldane, "Mechanism, Life, and Personality" (1913).
O. Hammarsten, "A Textbook of Physiological Chemistry" (trans. New York, 1911).
L. J. Henderson, "The Fitness of the Environment" (New York, 1913).
E. Hering, "On Memory as a General Function of Organised Matter," trans. in Samuel Butler's "Unconscious Memory" (1910).
O. Hertwig, "The Cell: Outlines of General Anatomy and Physiology" (trans. 1895).
L. Hill, "Recent Advances in Physiology" (1906).
Jacques Loeb, "Studies in General Physiology" (2 vols. Chicago, 1905). "Dynamics of Living Matter" (London, 1906).
——— "The Mechanistic Conception of Life" (Chicago, 1911).

W. McDougall, "Body and Mind" (1911).
Benjamin Moore, "The Origin and Nature of Life" (Home University Library).
H. Przibram, "Experimental Zoology" (Part I. trans. 1908).
Max Verworn, "General Physiology" (trans. London, 1899).
——— "Irritability, a Physiological Analysis of the General Effect of Stimuli in Living Substance" (New Haven, 1913).
Wells, "Chemical Pathology" (New York, 1907).
E. B. Wilson, "The Cell in Development and Inheritance" (Columbia University Biol. Series, new ed. 1911).

COMPARATIVE PHYSIOLOGY

*F. Jeffrey Bell, "Comparative Anatomy and Physiology" (London, 1887). An admirable introduction.
Claude Bernard, "Phénomènes de la vie communs aux animaux et aux végétaux" (Paris, 1878).
Paul Bert, "Léçons sur la physiologie comparée de la respiration" (1870).
G. Bunge, "Physiological and Pathological Chemistry" (trans. 1890).
C. M. Child, "Senescence and Rejuvenescence" (Chicago, 1915).
C. B. Davenport, "Experimental Morphology" (2 vols. 1897–1899).
O. von Fürth, "Vergleichende chemische Physiologie der niederen Tiere" (1903).
A. B. Griffiths, "Physiology of the Invertebrata" (1892).
Halliburton, "Physiological Chemistry" (London, 1891).
D. Fraser Harris, "Nerves" (Home University Library).
C. F. W. Krukenberg, "Vergleichend-physiologische Studien" and "Vorträge" (Heidelberg, 1882–1888). Quite fundamental studies.
Metchnikoff, "Comparative Physiology of Inflammation."
*M. I. Newbigin, "Colour in Nature" (London, 1898). A very educative introduction to the problems of comparative physiology, and an important contribution to the particular problem of coloration.
A. Pütter, "Vergleichende Physiologie" (Jena, 1911).
C. S. Sherrington, "Integrative Action of the Nervous System" (1906).
J. Bland Sutton, "General Pathology."
*M. Verworn, "General Physiology" (trans. 1899).
Hans Winterstein, "Handbuch der Vergleichenden Physiologie" (Jena, 4 vols. 1910–1914).

PARTICULAR PHYSIOLOGICAL PROBLEMS

Colour:

F. E. Beddard, "Animal Colouration" (1892).
E. B. Poulton, "Colours of Animals" (Internat. Sci. Series, 1890).
M. I. Newbigin, "Colour in Nature" (1898).

Colour (*continued*):
G. Bohn, "L'Evolution du pigment" (Series Scientia, Paris, 1901).
Grant Allen, "Colour Sense."
Gerald H. Thayer, "Concealing-coloration in the Animal Kingdom, A Summary of A. H. Thayer's Discoveries" (New York, 1909).

Luminescence, etc.:
C. F. Holder, "Living Lights."
E. Mangold, "Die Produktion von Licht" in Vol. III. of Winterstein's Vergleichende Physiologie (Jena, 1910–1914).
R. Tigerstedt, "Die Produktion von Wärme und der Wärme-haushalt" Ibid. (Jena, 1910–1914).
S. Garten, "Die Produktion von Elektricität" Ibid. (Jena, 1910–1914).

Movement:
Pettigrew, "Animal Locomotion" (Internat. Sci. Series, 1873).
Marey, "Animal Mechanism" (Internat. Sci. Series, 1874).
——— "Le Vol des Oiseaux" (Paris, 1890).
Headley, "Life and Structure of Birds."
McKendrick, "Life in Motion" (1892).

Regeneration:
T. H. Morgan, "Regeneration" (Columbia University Biol. Series).
A. Weismann, "The Evolution Theory" (2 vols. trans. 1904).

Length of Life:
E. Ray Lankester, "On Comparative Longevity in Man and the Lower Animals" (1870).
A. Weismann, "Biological Memoirs" (trans. Oxford, 1889).

ANIMAL BEHAVIOUR AND COMPARATIVE PSYCHOLOGY

J. Mark Baldwin, "The Story of the Mind" (Library of Useful Stories, 1899).
Binet, "La Vie psychique des micro-organismes" (1891).
G. Bohn, "La Nouvelle psychologie animale" (Paris, 1911).
——— "La Naissance de l'intelligence" (Paris, 1909).
L. Busse, "Geist und Körper, Seele und Leib" (Leipzig, 1903).
Samuel Butler, "Life and Habit" (London, 1878).
——— "Unconscious Memory."
A. Espinas, "Des Sociétés animales, étude de psychologie comparée" (Paris, 1877).
J. H. Fabre, "Souvenirs entomologiques, études sur l'instinct et les mœurs des insectes" (9 vols. Paris, 1879).
P. Girod, "Les Sociétés chez les animaux" (Paris, 1890).
Groos, "Play of Animals" (trans. London, 1898).
P. Hachet-Souplet, "La Genèse des instincts, étude expérimentale" (Paris, 1911).

E. von Hartmann, "Das unbewusste vom Standpunkte der Physiologie und Descendenztheorie" (2nd ed. Berlin, 1877).
*L. T. Hobhouse, "Mind in Evolution" (revised ed. 1915).
F. Houssay, "Les Industries des animaux" (Paris, 1889; trans. Contemporary Sci. Series, 1893).
*Jennings, "Behaviour of the Lower Organisms" (Columbia University Biol. Series, 1906).
G. H. Lewes, "Problems of Life and Mind" (1874–1879).
J. Loeb, "Comparative Physiology of the Brain" (London, 1901).
——— "Tropismen" (In Winterstein's Vergleichende Physiologie).
J. Lubbock (Lord Avebury), "Ants, Bees, and Wasps" (Internat. Sci. Series, London, 1883).
*W. MacDougall, "Primer of Physiological Psychology."
*——— "Psychology" (Home University Library).
E. Mach, "Contributions to the Analysis of the Sensations" (trans. Chicago, 1897).
W. Mitchell, "Structure and Growth of the Mind" (1907).
C. Lloyd Morgan, "Animal Behaviour" (1900).
*——— "Introduction to Comparative Psychology" (1894).
*——— "Habit and Instinct" (1897).
——— "Instinct and Experience" (1912).
J. J. Murphy, "Habit and Intelligence."
G. W. and E. G. Peckham, "Wasps, Social and Solitary."
G. J. Romanes, "Animal Intelligence" (Internat. Sci. Series, 4th ed. 1886).
——— "Mental Evolution of Animals" (1883).
——— "Jellyfishes, etc." (Internat. Sci. Series, London, 1885).
*E. M. Smith, "The Investigation of Mind in Animals" (Cambridge, 1915).
G. H. Schneider, "Der thierische Wille" (Leipzig, 1880).
K. C. Schneider, "Vorlesungen über Tierpsychologie" (Leipzig, 1909).
Herbert Spencer, "Principles of Psychology" (1855 and 1876).
E. L. Thorndike, "Animal Intelligence" (New York, 1911).
J. von Uexküll, "Umwelt und Innenwelt der Tiere" (Berlin, 1912).
Max Verworn, "Psycho-physiologische Protisten-Studien" (Jena, 1889).
*M. F. Washburn, "The Animal Mind" (New York, 1909).
Wasmann, "Instinkt und Intelligenz im Thierreich" (1897).
*J. B. Watson, "Behaviour, an Introduction to Comparative Psychology" (New York, 1914).
H. E. Ziegler, "Der Begriff des Instinkts" (2nd ed. Jena, 1910).

GENERAL MORPHOLOGY

Patrick Geddes, article Morphology, "Encyclopædia Brit."
Ernst Haeckel, "Generelle Morphologie" (Berlin, 1866; reprinted in condensed form, 1906).
*E. S. Russell, "Form and Function" (London, 1916). A book of remarkable scholarship and biological insight.

HERBERT SPENCER, "Principles of Biology" (London, 1864–1866, revised ed. 1908).
*JULIAN S. HUXLEY, "The Individual in the Animal Kingdom" (Cambridge Manuals of Science and Literature, 1912).
E. PERRIER, "Les Colonies animales" (Paris, 1881).

CLASSIFICATION

Articles in latest edition of "Encyclopædia Britannica."
H. GADOW, "Classification of Vertebrata" (1898).
W. A. HERDMAN, "Phylogenetic Classification of Animals."
E. RAY LANKESTER, article Zoology ("Encyclopædia Brit."); also in "Advancement of Science."
——— Introduction to Part II. of "Treatise on Zoology" (1900).
MONTGOMERY, "Analysis of Racial Descent in Animals" (1906).
*GEOFFREY SMITH, "Primitive Animals" (Cambridge Manuals of Science and Literature).

COMPARATIVE ANATOMY

Besides the older works of Owen, Huxley, Gegenbaur, etc.:
BÜTSCHLI, "Vorlesungen über vergleichende Anatomie" (3 vols.).
A. CHAUVEAU, "Comparative Anatomy of Domesticated Animals" (trans. New York, 1891).
A. ECKER, "Anatomy of the Frog" (trans. Oxford, 1889).
*ARTHUR KEITH, "The Human Body" (Home University Library).
——— "Human Embryology and Morphology" (1904, 3rd ed. 1913).
W. KRAUSE, "Die Anatomie des Kaninchens" (2nd ed. Leipzig, 1884).
A. LANG, "Textbook of Comparative Anatomy" (3 vols.).
ST. GEORGE MIVART, "The Cat, an Introduction to the Study of Backboned Animals" (1881).
OPPEL, "Vergleichende mikroscopische Anatomie" (6 vols. 1896–1905).
S. H. REYNOLDS, "The Vertebrate Skeleton" (2nd ed. 1913).
SCHIMKEWITSCH, "Vergleichende Anatomie der Wirbeltiere" (1909).
C. VOGT and E. YUNG, "Traité d'anatomie comparée pratique" (2 vols. 1888–1894).
*R. WIEDERSHEIM, "Comparative Anatomy of Vertebrata," trans. by W. N. Parker (3rd ed. London, 1907).

STUDY OF MINUTE STRUCTURE

O. HERTWIG, "The Cell: Outlines of General Anatomy and Physiology" (trans. 1895).
A. LABBÉ, "La Cytologie expérimentale" (Paris, 1898).
E. A. SCHÄFER, "Essentials of Histology" (8th ed. 1910).
K. C. SCHNEIDER, "Lehrbuch der vergleichenden Histologie der Tiere" (Jena, 1902).

C. E. WALKER, "Essentials of Cytology" (1907).

*E. B. WILSON, "The Cell in Development and in Inheritance" (rev. ed. 1911).

A FEW REPRESENTATIVE BOOKS DEALING IN VARIOUS WAYS WITH SPECIAL GROUPS

MAMMALS:

W. H. FLOWER and R. LYDEKKER, "Mammals, Living and Extinct" (1891).

F. E. BEDDARD, "Mammals" in Cambridge Natural History (Vol. X. 1902).

R. LYDEKKER, "British Mammals" (1896).

SIR HARRY JOHNSTON, "British Mammals" (1903).

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